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Observations on Recruitment of Postlarval Spiny Lobsters, *Panulirus argus*, to the South Florida Coast

EDWARD J. LITTLE, JR.

Florida Department of Natural Resources
Marine Research Laboratory
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ABSTRACT

Little, E. J., Jr., 1977. Observations on Recruitment of Postlarval Spiny Lobsters, *Panulirus argus*, to the South Florida Coast. Fla. Mar. Res. Publ. No. 29. 35 pp. Semi-quantitative data on recruitment taken variously at several localities by Witham habitats (floating artificial substrates), plankton nets, and examination of natural fouling communities from August 1964 through September 1971 is summarized. Postlarvae (= pueruli) were collected during all months, but recruitment peaks were more frequent during spring and fall, except in the lower Florida Keys where summer peaks were occasionally noted. Low summer recruitment along southeast Florida was sometimes associated with reduced salinities from freshwater runoff, but similar recruitment decreases elsewhere could not be attributed to salinity reductions. Noctural recruitment peaks during flooding tides in new and first quarter moon phases (81.3% in 1967, 96.8% in 1968) were further substantiated. Daily catches from similar adjacent Witham habitats varied considerably, indicating need for further study to develop quantitative sampling techniques. Postlarvae were more abundant in habitats placed in nearshore shallows (depths about 0.5-1.0 m M.L.W.) than in those placed in deeper channels, suggesting the importance of the nearshore environment as juvenile nursery areas. In 30 monthly plankton samples taken with a three-net vertical array at Whale Harbor Channel (depth about 3.0 m), 90% of postlarvae were taken at surface or mid-depth. Ambient light may exert an inhibitory effect upon recruitment, but normal changes in temperatures and salinities probably do not greatly affect recruitment magnitude.

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INTRODUCTION

The western Atlantic spiny lobster, *Panulirus argus* (Latreille, 1804), occurs primarily on shallow continental and insular shelves from North Carolina (Hay and Shore, 1918; Williams, 1965) and Bermuda through the Gulf of Mexico and the Caribbean Basin to Rio de Janeiro (Smith, 1948; Chace and Dumont, 1949). This tropical species supports valuable commercial and sports fisheries throughout much of its range. From 1969 through 1973, commercial landings for Florida waters alone averaged 2.29 x 10^6 kg/yr, worth approximately $4.27 million/yr (Johnson, 1974). While general habits and life history have been summarized by Crawford and De Smidt (1922), Smith (1954), and Buesa Más (1961), effects of environmental influences and fishing pressure on stock dynamics are virtually unknown.

Thorough knowledge of population dynamics is essential to effective management of fishery stocks (Burkenroad, 1951; Rounsefell and Everhart, 1953; Cushing, 1973). As suggested by Cushing (1973), levels of recruitment to fishery stocks often result from changes in survival of young. Accordingly, dynamics of the Florida lobster fishery might be greatly clarified by investigations on origin and recruitment of larvae and postlarvae and survival of juveniles on nursery grounds. Such studies have proven especially useful in understanding and predicting fluctuations in abundance of Atlantic mackerel (Sette, 1943), Gulf menhaden (Turner et al., 1974), pink shrimp (Baxter, 1963; Kutkuhn, 1966; Munro et al., 1968; Roessler and Rehrer, 1971), and Australian spiny lobsters, *Panulirus longipes* (A. Milne-Edwards, 1868) (Chittleborough and Thomas, 1969; Phillips, 1972).

Certain problems complicate recruitment studies of larval and postlarval lobsters. Lewis (1951) described morphological development of planktonic larvae he believed to be *P. argus*. These larvae passed through eleven dissimilar stages during a developmental process which he estimated might require as long as six months. He suggested larvae occurring off southeast Florida were probably spawned in the West Indies or in the Gulf of Mexico. Offspring of Florida stocks were probably swept northward in the Gulf Stream to an unknown fate. Ingle et al. (1963), Sims and Ingle (1966), Austin (1972), and Hammer (1974) subsequently demonstrated year-round transport of palinurid larvae to Florida via the Yucatan and Florida Currents. Exact sources of these larvae, their contribution to Florida stocks, and circumstances surrounding their recruitment to inshore waters have yet to be determined, primarily because of uncertainty in specific identification of planktonic larvae. Samples may contain a mixture of different (and for some species, undescribed) stages of *P. argus*, *P. guttatus* (Latreille, 1804), and *P. laevicauda* (Latreille, 1817) (Provenzano, 1968; Austin, 1972; Hammer, 1974; Richards, 1974; Lyons and Little, 1975). Duration of each larval stage, extent of the entire larval phase, and age of individual larvae have not been conclusively determined for any of these species. Such problems are compounded by the relative paucity of larvae (especially later stages) in plankton samples (Lewis, 1951; Sims and Ingle, 1966; Sweat, 1968).

Even terminology designating the several phases of palinurid life history is presently controversial. Following the rationale of Lyons (1970), the term "larvae" as used here encompasses the various phyllosome stages described for *P. argus* by Lewis (1951). The term "postlarvae" as used here denotes only those postmetamorphic lobsters (regardless of degree of pigmentation) called "pueruli" or "first stage postlarvae" by Lewis et al. (1952), Sweat (1968), and Witham et al. (1968). Lobsters which have molted from the postlarval form but are not yet mature are herein termed "juveniles", the initial juvenile stage corresponding to the "second stage postlarva" as described by Lewis et al. (1952).

Postlarvae and early juveniles of *P. argus* have proven more amenable to study than have larvae. Lewis et al. (1952) described morphological development of postlarvae and juveniles; growth, habits, and seasonal abundance were also discussed. Witham et al. (1964) showed that postlarvae and juveniles could be collected throughout the year from fouling communities in the Indian River near Stuart, Florida (Figure 1). Further studies (Witham et al., 1968) led to development of a floating, artificial substrate (Witham habitat) simulating a fouling community which dependably attracted postlarvae. Sampling with this device indicated that recruitment to inshore nursery grounds is affected by influxes of postlarvae, chiefly at night during periods of new and first quarter moons. Studies in the Florida Keys (Sweat, 1968) showed that natant postlarvae are components of night plankton entrained in channels between Keys. However, late stage larvae are absent there, indicating offshore metamorphosis. Lunar periodicity of recruitment was again noted. Presence of postlarvae in surface Witham habitats, but not in benthic artificial habitats at the same localities, further demonstrated planktonic recruitment.

To provide more information on recruitment to inshore nurseries, the Florida Department of Natural Resources (FDNR) conducted additional studies from 1967 through 1971. The St. Lucie Inlet-Indian River lagoonal system and inshore waters of the Florida Keys were sampled by plankton nets, Witham habitats, and examination

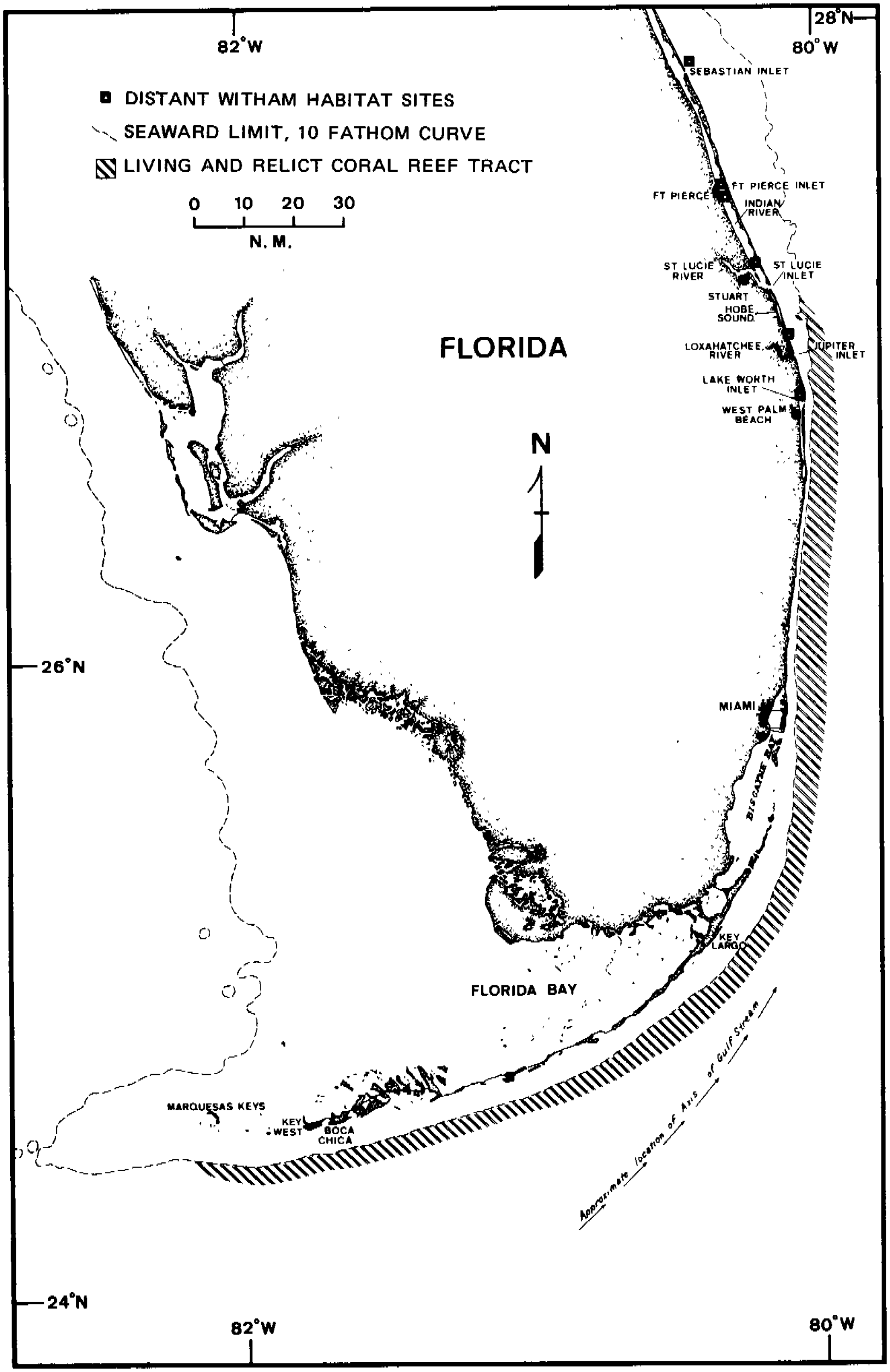

Figure 1. Study localities, south Florida coast.

of natural fouling communities. This paper reports these data and those collected from 1969 until 1971 by Mrs. Jean Holbert at Upper Matecumbe Key. Data originally reported by Witham et al. (1968) and Sweat (1968) is again presented to complement discussion of these subsequent studies.

STUDY REGION CHARACTERISTICS

LOWER FLORIDA EAST COAST

Recruitment studies were conducted in the Indian River north of Stuart (Figure 2) and in the Intracoastal Waterway between St. Lucie Inlet and Jupiter Inlet (Figure 3). These elongate, narrow lagoons are separated from the Atlantic Ocean by Hutchinson and Jupiter Islands, respectively.

The maritime climate is predominantly moist and subtropical and greatly influenced by strong southeast trade winds during most of the year (Hela, 1952a). Thus, rainfall is especially abundant in summer and autumn. Tropical depressions

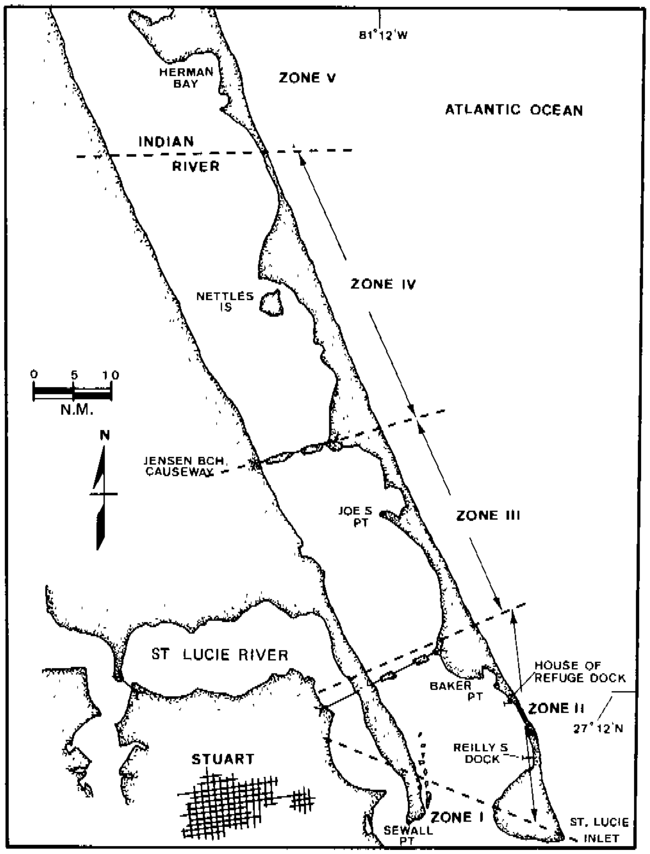

Figure 2. Postlarval lobster sampling zones, natural habitat study, Indian River.

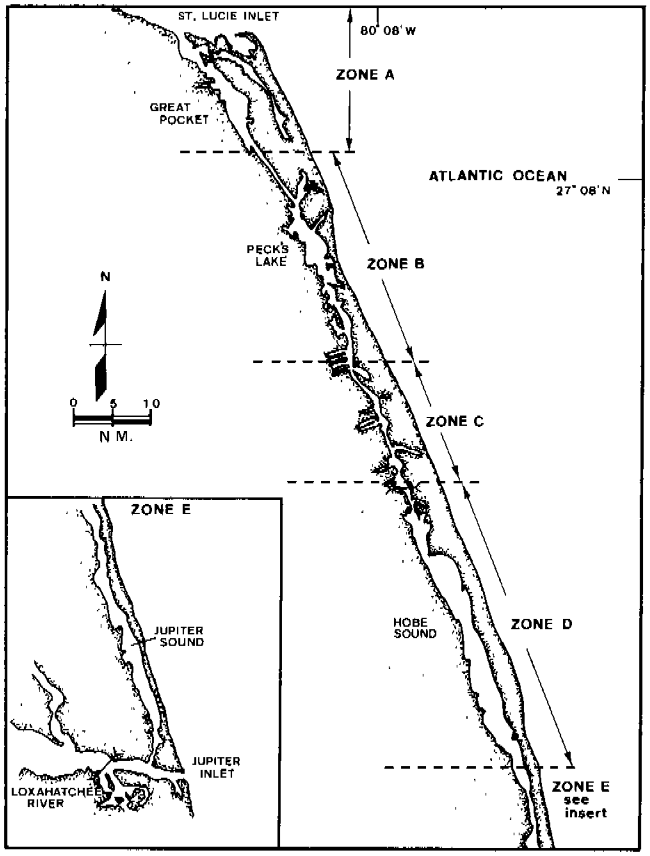

Figure 3. Postlarval lobster sampling zones, natural habitat study, St. Lucie to Jupiter Inlets.

occasionally bring additional rains ultimately effecting marked changes in hydrography and marine life of some portions of the study area (Gunter and Hall, 1963; Christensen, 1965; Witham et al., 1968). Although temperatures are primarily subtropical, cold polar continental fronts may intermittently intrude during winter (U. S. Dept. Comm., 1969) and cause severe thermal stress among certain tropical marine organisms (Gunter and Hall, 1963).

Bathymetry of the lagoonal system is comparatively shallow, water depths of < 2.0 m being prevalent (U.S. Dept. Comm., 1972). Tidal flushing appears to be moderate. Ranges are approximately 79.0 cm at St. Lucie Inlet and 39.0 cm at Jupiter Inlet. Salinities are generally high throughout seaward portions of the study area. Witham et al. (1964) and Christensen (1965) report values seldom below 30 $^0/_{00}$ for the St. Lucie Inlet-Jupiter Inlet lagoonal system. Springer (1960), Witham et al. (1964), and Witham et al. (1968) report values seldom less than 25 $^0/_{00}$ for the Indian River near Stuart. Considerable reductions occur during periods of massive freshwater discharge from the St. Lucie and Loxahatchee Rivers

(Gunter and Hall, 1963; Christensen, 1965; Witham et al., 1968; Briel, 1974). Eddies from the nearby Florida Current (Florida Ocean Science Institute, 1971) transport oceanic waters shoreward, providing a mechanism for seeding inshore areas with lobster postlarvae. An additional but poorly understood influence in this area is summer aperiodic instrusion of cold oceanic water in the manner described by Taylor and Stewart (1959) for Cape Canaveral beaches. Such instrusions have distressed or even killed certain stenothermal tropical organisms within the study area (Christensen, 1965; Gilmore, 1974; William Lyons, FDNR, personal communication). Briel (1974) concludes that, except for localized high coliform counts, the Indian River estuary is not strongly influenced by domestic or industrial pollutants.

Within this transitional area, tropical Caribbean marine faunal assemblages are supplanted by warm temperate Carolinian assemblages (Parr, 1933; Clench, 1945; Abbott, 1957; Christensen, 1965; Work, 1969; Briggs, 1974; Gilmore, 1974). Tropical seagrasses and benthic algae are abundant (Phillips and Ingle, 1960; Phillips, 1961; Eiseman, 1974) and probably contribute to the richness of larval, postlarval, and adult fauna within the area (Springer, 1960; Gunter and Hall, 1963; Witham et al., 1964; Christensen, 1965; Gilmore, 1974; Young, 1974). Mangrove stands along many littoral areas may likewise contribute to overall inshore productivity in the manner described by Heald (1971).

FLORIDA KEYS

The Florida Keys rest on a wide, shallow, limestone platform bordering the Florida Straits (Figure 1). Climate is tropical and is typified by uniformly mild temperatures, markedly wet (June through October) and dry (December through April) seasons, and prevalence of easterly trade winds (U. S. Dept. Comm., 1970).

Such climate and the relatively shallow bathymetry of the shelf influence regional hydrography. Inshore water temperatures are generally warm and uniform from surface to bottom (Vaughan, 1918; Chew, 1954; Gorsline, 1963). Seasonal and local variations are determined by air temperature patterns. Because of seasonal changes in freshwater runoff to Florida Bay and influence of the Florida Current, salinities are also locally variable (Turney and Perkins, 1972). Those near the shelf margin, however, usually average approximately 36.0 ‰ (Dole and Chambers, 1918). Salinities in central Florida Bay range from 27.0 ‰ to 41.0 ‰ (Hudson et al., 1970). Salinity stratification throughout the region is slight (Ginsburg, 1956; Gorsline, 1963). Dissolved oxygen in open waters is usually at or above saturation, and nutrients are seldom present in more than trace concentrations (Ginsburg, 1956; Jones, 1963).

Water circulation in the Florida Keys is poorly known. Eddies from the Florida current evidently produce a countercurrent along the shelf margin (Chew, 1954; Brooks and Niiler, 1975). Tides move these waters shoreward across the reef tract and Hawk Channel, thence into Florida Bay via channels between the Keys (Gorsline, 1963). A resultant westerly drift through Florida Bay and the southeastern Gulf of Mexico extends midway to the Tortugas (Koczy et al., 1960). At this point, waters either flow northward into the Gulf or turn southward toward the reef tract (Chew, 1954; Munro et al., 1968). Strong winds greatly modify these patterns (Chew, 1954; Ginsburg, 1956; Koczy et al., 1960) and also increase turbidities (Vaughan, 1919; Stephenson and Stephenson, 1950; Ginsburg, 1956). Degradations of the Loop Current may also wash over the southwest Florida shelf and through the Keys (Maul, 1974).

Description of a tropical, Caribbean ecosystem as complex as that of the Florida Keys is beyond the scope of this paper. Several natural, subjectively identified biotopes in this region, however, appear to be particularly significant to the ecology of spiny lobsters.

Massive, but often discontinuous, reefs formed by corals and other organisms lie near the seaward margin of the Keys shelf (Figure 4). Adult spiny lobsters congregate at these structures, and fishing pressure at such localities is often intensive. Vaughan (1910), Ginsburg (1956), Starck (1968), and Hoffmeister (1974) describe origin, structure, biota, and ecological role of the Keys reef tract.

The inner shelf (Hawk Channel Lagoon), as described by Ginsburg (1956), parallels the reef tract and extends shoreward to the Keys. Lush seagrass meadows (*Thalassia testudinum* König, *Halodule wrightii* Aschers, and *Syringodium filiforme* Kutzing in Hoenhacker), coral patch reefs, and an abundance of calcareous algae typify the area. Juvenile spiny lobsters are common here. Principal ecological attributes of this biotope can be inferred from Stephenson and Stephenson (1950), Voss and Voss (1955), Phillips (1959), Springer and McErlean (1962), Jones (1963), Kier and Grant (1965), and Chesher (1974).

Florida Bay and shallow waters between Keys are characterized by seagrass meadows, sandy bottoms, extensive mangrove shorelines, and mud banks. Biota of these frequently turbid shallows is distinctly different from that of more seaward biotopes (Tabb et al., 1962; Hudson et al., 1970; Howard et al., 1970; Turney and Perkins, 1972; Chesher, 1974). Sweat (1968) commonly found postlarvae and juvenile lobsters in such nearshore shallows.

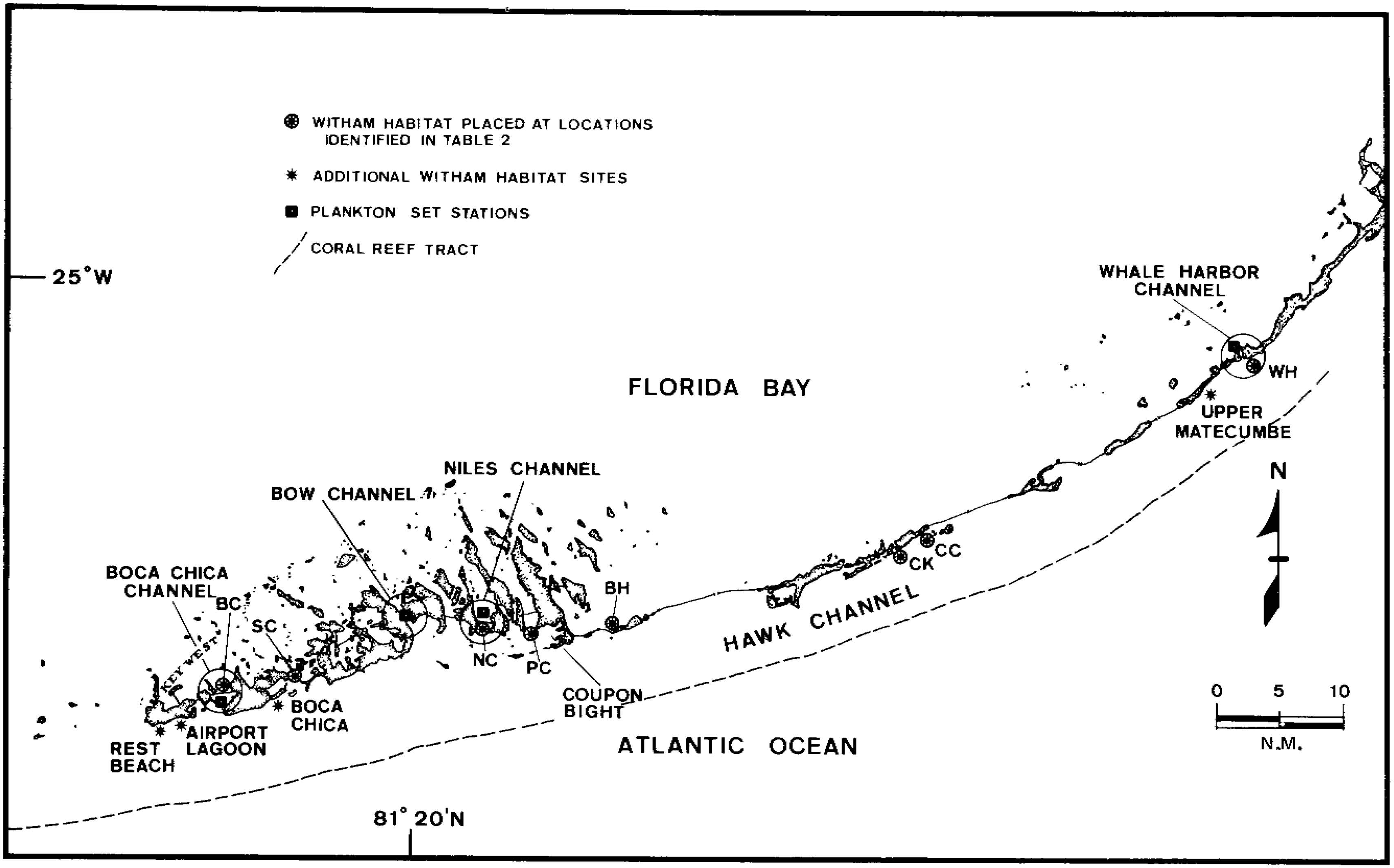

Figure 4. Witham habitat and plankton net set stations, Florida Keys.

METHODS AND MATERIALS

Except where noted in following sections, recruitment of postlarval spiny lobsters was monitored using floating Witham habitats (Figure 5).

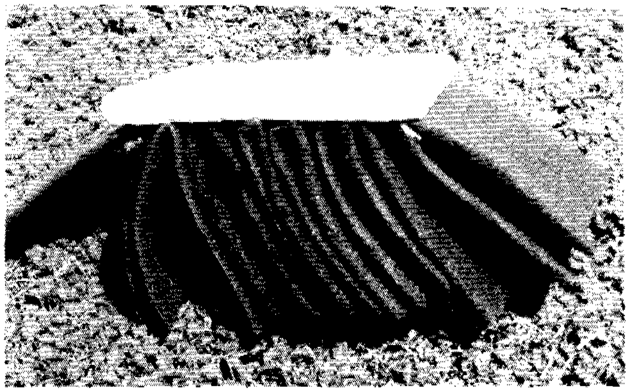

Figure 5. Witham habitat from the House of Refuge study area.

Float materials and habitat dimensions occasionally departed from the design originally described by Witham et al. (1968), but such changes were too minor to alter effectiveness. More substantial variations occurred, however, among webbing materials in the size and number of empty void spaces they contained. Initially, closely woven nylon webbing was used in the Indian River study. Later, as habitat design evolved, polypropylene webbing and vinyl webbing, both with larger and more numerous void spaces, were used. Habitats used in the Florida Keys were similarly modified. At both localities number of webbing "pages" was held constant. Postlarval and juvenile lobsters were removed from each habitat after examination.

LOWER FLORIDA EAST COAST

Witham et al. (1964) collected postlarvae from June 1963 through July 1964 by examining fouling organisms growing on mangrove prop roots and submerged tree limbs. Nonquantitative but useful data on times and places of postlarval lobster abundance resulted. Studies were continued through August 1965 and are reported herein. Data presented by Witham et al. (1964) are also discussed. Methods were similar to those of Witham et al. (1968). The study area was arbitrarily partitioned into sampling zones (Figures 2, 3). Varying areas along different lengths of shoreline were sampled monthly. Salinities and temperatures were determined (Witham et al., 1964). Ecological conditions in some zones can be inferred from Springer (1960), Phillips and Ingle (1960), Phillips (1961), Gunter and Hall (1963), Christensen (1965), and Young (1974).

The Witham habitat facilitated more quantitative, consistent collection of postlarvae than did sampling of natural habitat. Witham et al. (1968) reported recruitment at the House of Refuge dock (Figure 2) from December 1964 through November 1966, and at several distant sites from October 1965 through October 1967. Reported herein are unpublished data on recruitment from December 1966 through September 1968 in the vicinity of the House of Refuge dock and from November 1967 through August 1968 at selected distant habitats (Table 1). The latter were examined monthly between new and first quarter moons. The unpublished House of Refuge data and data reported by Witham et al. (1968) for that site are presented in a standardized catch/day/habitat (CPUE) format:

TABLE 1. LOCATION OF SELECTED DISTANT WITHAM HABITAT STATIONS.

Location	Latitude	Longitude
Sebastian Inlet	27°57'38" N	80°26'55" W
Little Jim Island	27°28'42" N	80°18'45" W
Ft. Pierce Pier 66	27°27'28" N	80°19'06" W
Hobe Sound (County Line)	26°58'03" N	80°04'55" W
Lake Worth at Singer Island	26°47'09" N	80°02'25" W

$$\text{CPUE} = \frac{\Sigma \text{ postlarvae}}{\Sigma \text{ individual habitat samples}}$$

This procedure was not used by Witham et al. (1968). Because there were not sufficient data to examine effects of postlarval accumulation in habitats, these effects were not accounted for in instances when samples were not made every day. The first Witham habitat was suspended at the House of Refuge dock (water depth 1.0 m) on April 20, 1965; additional habitats were added intermittently until studies ended in September 1968. Usually three to five habitats were deployed at any one time. They were checked at irregular intervals through August 14, 1965. Daily morning (0700-1100) and afternoon (1600-1800) checks were subsequently initiated and continued through January 16, 1967. Beginning on January 17, 1967, only morning checks were conducted. Frequency of examination was reduced to Mondays, Wednesdays and Thursdays after September 20, 1967.

Two Witham habitats were deployed approximately 1.0 km south of the House of Refuge dock. These habitats were attached to Reilly's dock (Figure 2) in 1.0 m of water from January 23, 1967 through September 19, 1967, and were checked in the manner and frequency described for House of Refuge dock habitats during this period. Temperatures and salinities were determined as per Witham et al. (1968).

FLORIDA KEYS

The Keys produce most lobsters caught in Florida waters (Robinson and Dimitriou, 1963a). Several lobster investigations have been conducted here (Crawford and De Smidt, 1922; Schroeder, 1924; Dawson and Idyll, 1951; Robinson and Dimitriou, 1963a, 1963b; Sims and Ingle, 1966; Davis, 1974; Warner, 1975). Recruitment studies were initiated in the Keys to complement those already underway at Stuart. Initial portions of these studies were discussed by Sweat (1968). Reported herein are additional recruitment studies using Witham habitats deployed along the shoreline of Upper Matecumbe Key from February 1969 through February 1971; at selected channels (Table 2) between Key West and Whale Harbor from January 1970 through August 1970; and along the shoreline of Boca Chica Key from October 1970 through September 1971 (Figure 4). Data previously presented by Sweat (1968) are reinterpreted on a CPUE basis to show recruitment patterns at his two most productive sites, Airport Lagoon and Rest Beach (Figure 4).

ATLANTIC SHORE, UPPER MATECUMBE KEY

This site (24°55′00″N, 80°37′48″W) was located 75 m off a sandy beach on a shallow (≅ 1 m) sand and *Thalassia* flat. Seasonal salinity and temperature regimes probably did not differ markedly from those reported by Springer and McErlean (1962) for similar, nearby shoreline. Tidal currents were apparently weak. Various unidentified species of algae formed loose matted carpets over much bottom (Mrs. Jean Holbert, personal communication).

Studies here were adjunct to investigations of other organisms occurring on Witham habitats. Sampling methods were not as consistent as in some other studies reported herein. Numbers of habitats deployed increased during the term of study; one was checked until June 23, 1969, three were checked until January 28, 1970, and five were subsequently examined. Examinations were generally at low tide. Habitats were seldom examined during full or last quarter moons. Intervals between checks varied but were usually daily during new and first quarter moons.

SELECTED CHANNELS, KEY WEST TO WHALE HARBOR BRIDGE

One Witham habitat was deployed at each of eight sites (Table 2) along inshore Keys channels (Figure 4). General hydrological and ecological features differed between sites. With few exceptions, habitats were examined at least twice weekly (primarily Tuesdays and Fridays). Intervals between habitat checks at site WH were less regular since a boat and calm weather were required to

TABLE 2. LOCATIONS AND CHARACTERISTICS OF WITHAM HABITAT STATIONS NEAR CHANNELS, FLORIDA KEYS.

Station Designation	N. Lat. W. Long.	Locality Name	Depth (m)	Tidal Currents[1]	Bottom Vegetation[2]
BC	24°34′54″ 81°38′53″	Boca Chica Channel	.3 - .5	weak	abundant
SC	24°35′20″ 81°38′53″	Shark Channel	1.0	strong	common
NC	24°39′40″ 81°26′15″	Niles Channel	.3	weak	sparse
PC	24°40′06″ 81°22′20″	Pine Channel	.6	strong	sparse
BH	24°39′15″ 81°17′53″	Bahia Honda Channel	1.0	moderate	common
CK	24°44′40″ 80°58′50″	Crawl Key	.6	weak	sparse
CC	24°46′42″ 80°54′36″	Conch Key Channel	1.0	moderate	sparse
WH	24°56′12″ 80°36′40″	Whale Harbor Channel	1.5	strong	common

[1]Subjective estimates.

[2]Subjective estimates of the abundance of *Thalassia*, other marine grasses, and algae.

reach this offshore habitat. Checks were made without regard to tide stage. However, they usually were made between 0800-1100 for sites BC, SC, NC, and PC, and between 1100-1500 for sites BH, CK, CC, and WH.

ATLANTIC SHORE, BOCA CHICA KEY

Studies were initiated at Boca Chica Key to supplement the time-consuming, yet relatively unproductive investigation of recruitment in channels. Because the Boca Chica site was environmentally similar to other productive sites (Upper Matecumbe and Airport Lagoon), studies here were intended to determine if this biotope was indeed a place of appreciable lobster recruitment.

The site (24°33′36″N, 81°40′56″W) in shallows (depth 0.8 m M.L.W.) was 50 m offshore from a sandy beach. Bottom consisted of coarse calcerous sand and moderately abundant *Thalassia* and *Halodule*. No pronounced currents were apparent, but circulation was affected by moderate tidal exchange and wind influence.

Ecological characteristics and biota appeared to be typical of shallow *Thalassia* flats of the inner shelf. Benthic algae, especially *Laurencia potei* (Lamouroux) Howe, various Rhodophyta, and calcareous Chlorophyta were abundant. In slightly deeper waters (depths ≅ 1.0-1.5 m M.L.W.) immediately adjacent to the habitats, low limestone outcroppings, gorgonians, and numerous small stony corals were common. In many respects, ecological conditions at this site resembled those described by Voss and Voss (1955) for Soldier Key near Miami.

Sampling was intermittent. In most cases, at least four checks were made per month, all during daylight without regard to time or tide stage. Numbers of habitats varied. Five were sampled in September 1970, eight in October 1970, ten from November 1970 through May 22, 1971, and eight subsequently.

SOUTH SHORE, KEY WEST

Sweat (1968) reported recruitment to Witham habitats in the Key West vicinity without adjusting results for changes in sampling effort. Recruitment patterns were also biased by inclusion of data for inconsistently productive, unrepresentative sites. Using CPUE format, recruitment to the two most representative sites, Airport Lagoon and Rest Beach, is presented here to show seasonal, monthly, and geographic recruitment patterns.

Airport Lagoon (24°32′53″N, 81°45′36″W) and Rest Beach (24°32′40″N, 81°47′09″W) sites were located approximately 100-200 m off the south shore of Key West near *Thalassia* beds. Environmental characteristics of both appear typical of those prevailing in the Hawk Channel system. Sweat (1968) described bottom conditions at Airport Lagoon (depth 2.0-5.0 m) and presented photographs showing dominant vegetation (*Thalassia*, *Halimeda* spp., *Udotea* spp., and *Penicillus* spp.). Similar bottom cover apparently existed at the Rest Beach site (depth 2.0-3.0 m). Biota of Airport Lagoon is discussed in detail by Chesher (1974).

From January through December 1967, single Witham habitats were deployed at Airport Lagoon and Rest Beach. Both were usually checked between 0800-1400 at intervals of approximately two to four days without regard to hydrographic conditions.

WHALE HARBOR CHANNEL

Sweat (1968) reported methods and results of plankton sampling for lobster larvae and postlarvae in Whale Harbor Channel (Figure 4). His data are presented here for comparison with previously unpublished data taken by the National Marine Fisheries Service (NMFS) during March through August 1966 using identical methods at this site. In addition, previously unreported collections of postlarvae were made here and at Niles, Boca Chica, and Bow Channels (Figure 4) with surface and bottom 0.5 m nets described by Sweat (1968).

Currents and depths at all channels are not consistent and have not been studied in detail. From tidal current tables (U. S. Dept. Comm., 1975), charts, and field observations, it appears that flood currents are ≅ 0.5-1.0 m/sec, and depths are 2.0-3.0 m.

Sampling was done at Whale Harbor with the 30 cm diam surface, mid-depth, and bottom nets described by Sweat (1968). The 0.5 m net was attached to a line and held at the surface by the downstream current. This net was fished for the first hour of each two hour period in which the 30 cm nets were fished. During night flood tides, it was also fished during the new moon for 0.5 hr at Bow, Niles, and Boca Chica Channels. Additional Boca Chica samples were also taken during night and day ebbs and during day floods, all within 24 hr of the night flood tide samples.

RESULTS AND DISCUSSION

LOCALITIES AND PERIODS OF RECRUITMENT

In order to use changes in abundance of postlarval and juvenile lobsters in interpretation of population dynamics, the periods and localities normally conducive to recruitment must be determined. This provides a basis for designing more quantitative studies of lobster life history, as well as indicating if the population is comprised of simultaneously recruited cohort groups analogous to year classes in other fisheries.

ST. LUCIE ESTUARY AND INDIAN RIVER

In evaluating recruitment to the St. Lucie region, one must consider that abnormal changes in salinity and temperature profoundly affect survival and behavior of marine organisms. Salinities varied within normal limits in 1964 (Witham et al., 1964), 1965 (Witham et al., 1968), and 1967 (Figure 6), but were severely reduced in summers of 1966 (Figure 7) and 1968 (Figure 8) by freshwater discharges (Figure 9) from the St. Lucie flood control system (Witham et al., 1968). Recruitment may have been disrupted during the years 1966 and 1968, since Witham et al. (1968) demonstrated that salinities less than 20 $^{o}/oo$ are lethal to postlarvae. Water temperatures were not recorded frequently enough during 1963, 1964 and 1965 to be indicative of the prevailing regime. However, those measured in 1966, 1967 and 1968 (Table 3) appear characteristic of conditions to be expected, and feature no marked anomalies that might reduce recruitment.

Sampling of natural habitat during August 1964 through August 1965 showed postlarvae and early juveniles occurring throughout Indian River (Table 4) and Hobe Sound (Table 5). Abundances were consistently greatest at Jupiter Inlet (Zone E) and in the vicinity of the House of Refuge dock (Zone 2), declining northward in each lagoonal system. Two localities close to St. Lucie Inlet (Zones 1 and A) were usually unproductive due to scarcity of suitable habitat (Zone 1) and unfavorable current patterns (Zone A) (Mr. William Lyons, personal communication). In both lagoons, August through November, and March through May were the most productive periods. In the sampling period of June 1963 through July 1964, these months were also most productive in natural habitat sampling (Witham et al., 1964). In 1965, the same months, August through November and March through May, were most productive in planktonic postlarvae sampling (Witham et al., 1968).

Resolution of periods of postlarval recruitment, as determined by Witham habitat sampling at Indian River, can only be provisional. Substantial, often inconsistent, variations between monthly catches of individual habitats (Table 6) indicate the data may not accurately represent the true level of recruitment, even for months when there was similarity between catches of individual habitats. This occurs in daily catch data as well. Data for 1967 (Tables 6, 7) are probably the least biased. Unlike other years, in 1967 examinations were at frequent, regular intervals, the same habitats were deployed for most of the year, and salinities were not severely reduced. Still, magnitude and timing of recruitment often differed among habitats in the same location. Some habitats were at times more productive than others. These inconsistencies limit the confidence that can be placed solely on individual daily habitat catches. It is likely that succession of fouling assemblages on different habitats may have been elements in this variation, but there are no data to quantify this.

Witham habitat data, despite limitations, remain valuable because they substantiate the bimodal recruitment pattern noted in natural habitat sampling. In spring 1965, increased recruitment to the House of Refuge dock area was indicated by prototype artificial substrates (Witham et al., 1968) and by natural habitat sampling in Zone 2. Catches by both methods declined in June and July, then increased in August. Although natural habitat sampling was terminated at the end of August, the relatively high postlarval abundance in September 1965 seems genuine (Table 6). Again, there seems to have been increased recruitment to the Florida east coast from February through May 1966. House of Refuge habitats and the habitat placed approximately 225 km to the south at Key Largo (Witham et al., 1968) made increased catches. During summer 1966, few postlarvae were taken at House of Refuge habitats or at distant Florida east coast habitats (Witham et al., 1968), but catches increased somewhat from October through December. Increased recruitment from February through May 1967 is indicated by catches at House of Refuge, Reilly's dock and distant habitats. Catches then declined in summer, rising again in autumn. Many postlarvae were taken in December at the House of Refuge dock but not elsewhere. Next substantial recruitment occurred from March through May 1968, as indicated by House of Refuge data (Table 6) and the data for additional distant habitats (Table 8). Lack of recruitment to House of Refuge habitats during summer 1968 was probably caused by low salinities as in 1966, but a summer recruitment hiatus also occurred at distant habitats unaffected by flooding.

These data also substantiate lunar periodicity of recruitment first noted by Witham et al. (1968) for 1965 and 1966 sampling. In 1967 and 1968 (Table 9), most recruitment also occurred between three days before new moon and three days after first quarter moon. Agreement of recruitment

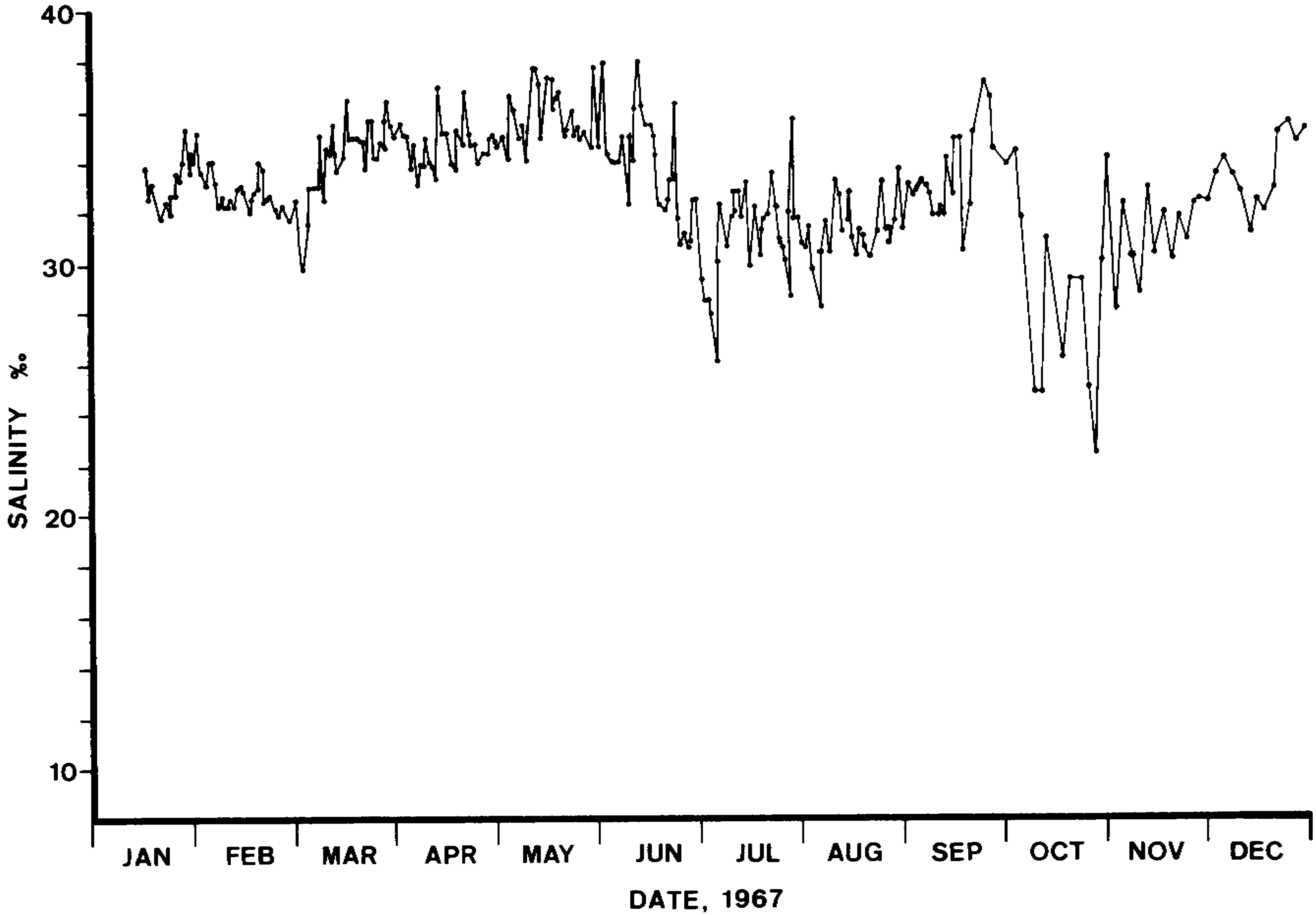

Figure 6. Daily salinities, House of Refuge dock, Indian River, 1967.

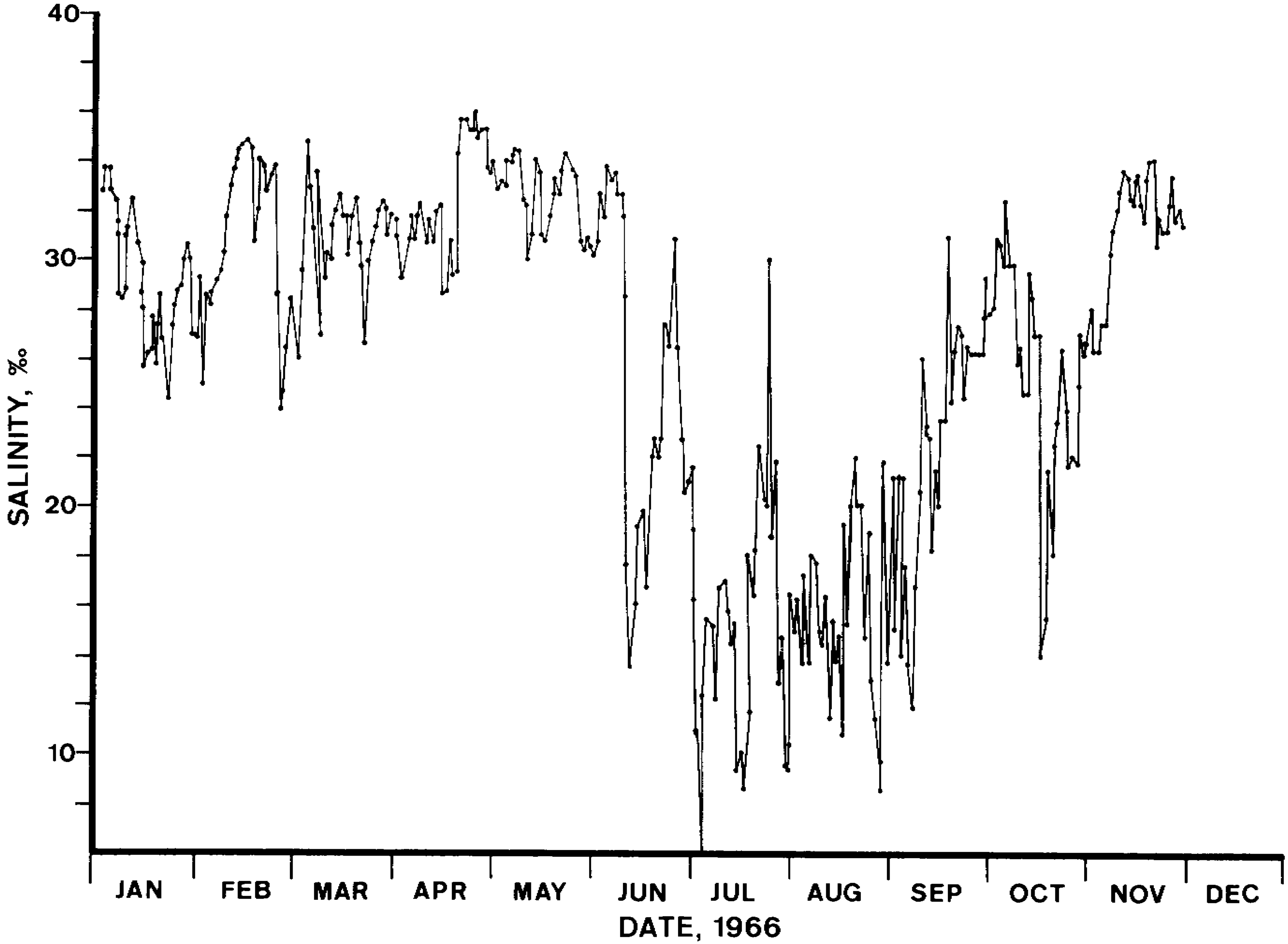

Figure 7. Salinities, House of Refuge dock, Indian River, 1966.

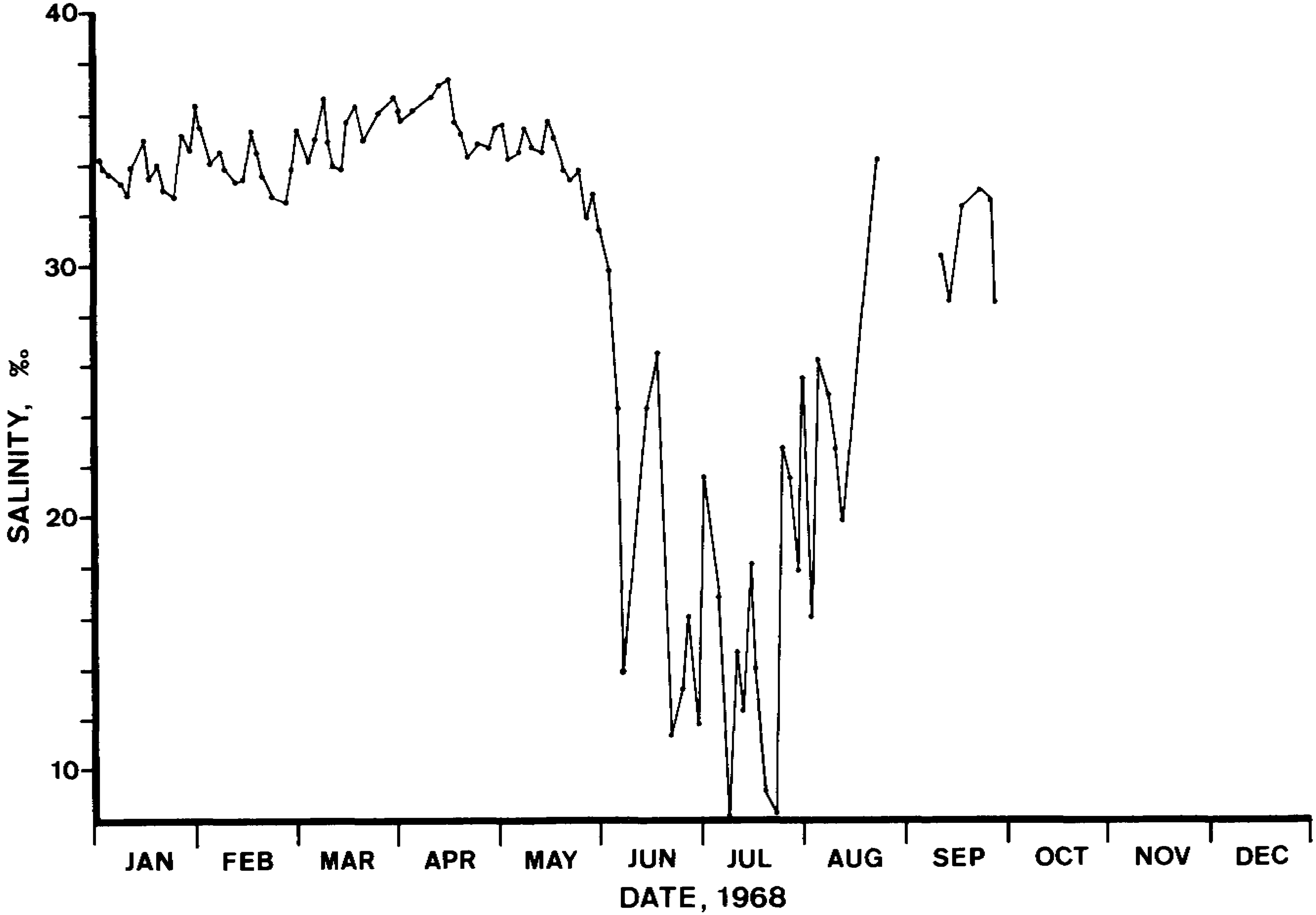

Figure 8. Salinities, House of Refuge dock, Indian River, 1968.

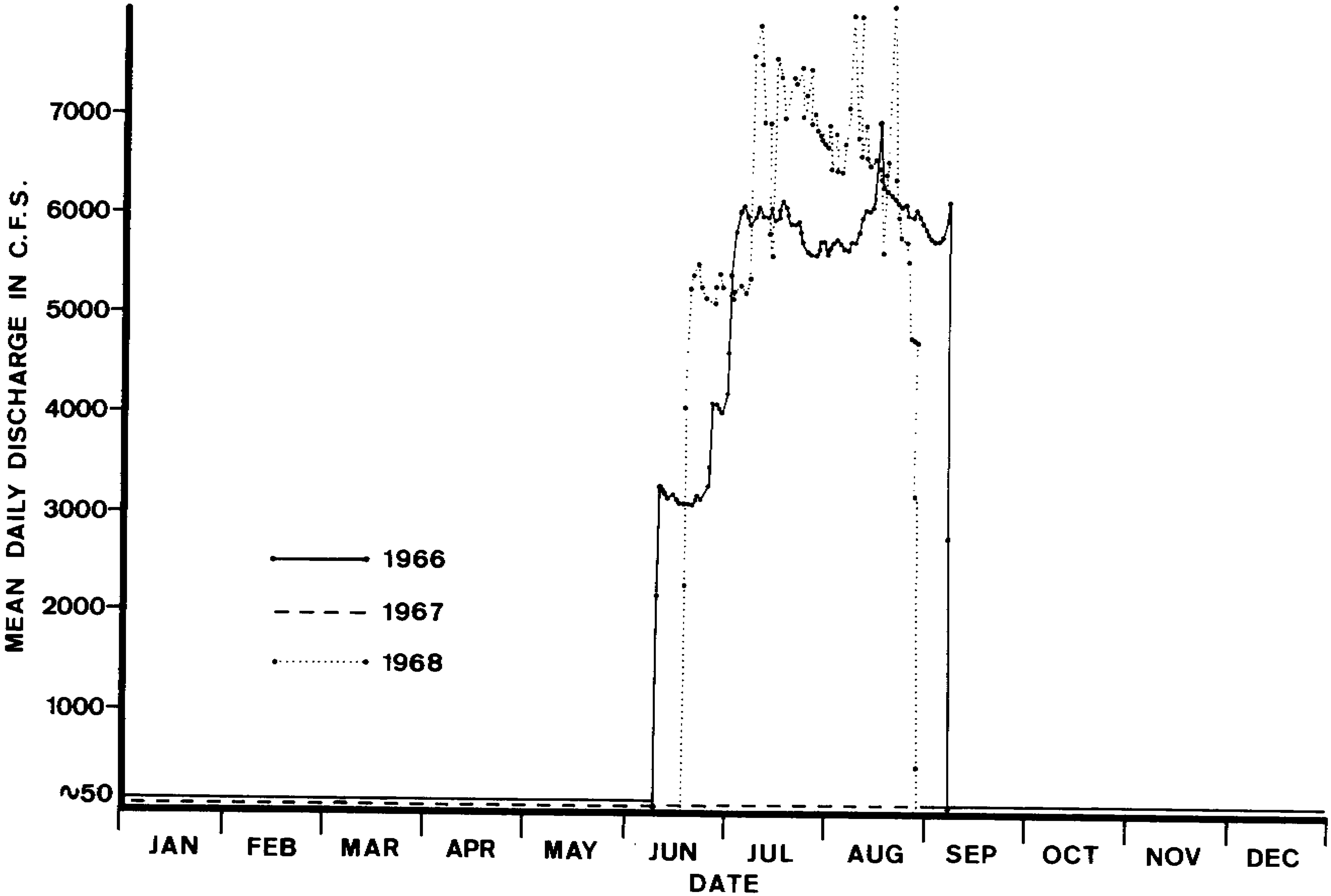

Figure 9. Freshwater discharges, cubic feet per second, (CFS), St. Lucie locks, 1966-1968.

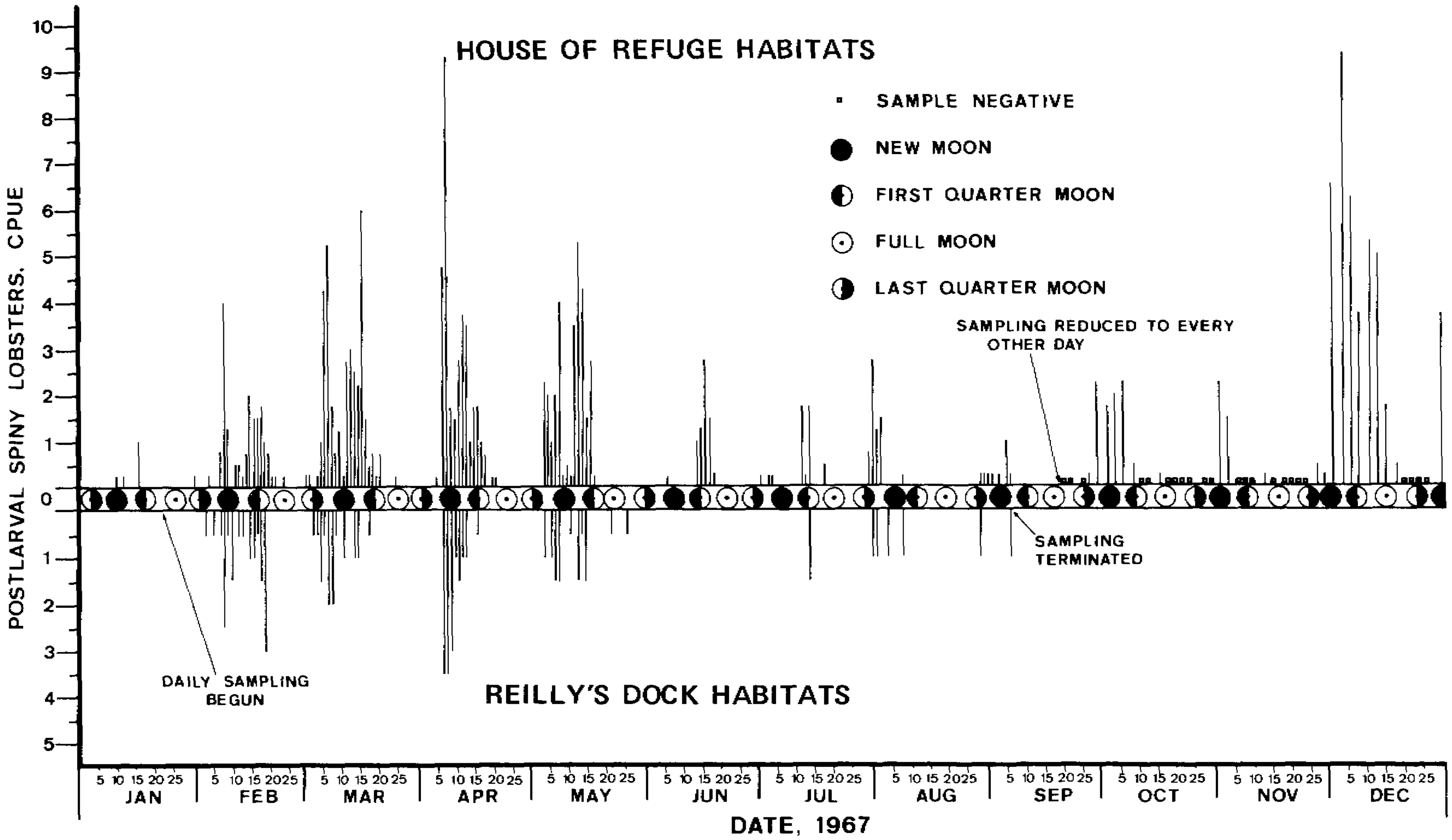

Figure 10. Postlarval spiny lobster CPUE from Witham habitats, House of Refuge and Reilly's dock, Indian River, 1967.

TABLE 11. MONTHLY ABUNDANCE OF LOBSTER POSTLARVAE, FLORIDA KEYS WITHAM HABITATS.

		Month											
Year	Site	J	F	M	A	M	J	J	A	S	O	N	D
1967	Airport Lagoon	8	16	4	145	26	22	53	30	5	5	0	23
No. individual habitat samples		7	8	8	8	10	8	6	10	2	4	6	5
Monthly average CPUE		1.14	2.00	.50	18.12	2.60	2.75	8.83	3.00	2.50	1.25	0	4.60
% of total CPUE		2.4	4.2	1.0	38.3	5.5	5.8	18.7	6.3	5.3	2.6	0	9.7
1967	Rest Beach	6	23	0	11	8	35	49	35	4	20	24	20
No. individual habitat samples		8	8	7	7	10	8	6	10	2	5	7	5
Monthly average CPUE		.75	2.88	0	1.57	.80	4.38	8.17	3.50	2.00	4.00	3.43	4.00
% of total CPUE		2.1	8.1		4.4	2.2	12.3	23.0	9.9	5.6	11.3	9.7	11.3
1969	Upper Matecumbe		12	25	44	21	13	39	94	47	28	11	5
No. individual habitat samples			9	13	23	14	6	26	60	51	36	18	9
Monthly average CPUE			1.33	1.92	1.91	1.50	2.17	1.50	1.57	.92	.78	.61	.56
% of total CPUE			9.0	13.0	13.0	10.2	14.7	10.2	10.6	6.2	5.3	4.1	3.8
1970	Upper Matecumbe	68	54	66	35	61	8	17	21	77	25	8	45
No. individual habitat samples		30	45	60	65	65	20	35	18	88	28	35	60
Monthly average CPUE		2.27	1.20	1.10	.54	.94	.40	.49	1.17	.88	.89	.23	.75
% of total CPUE		20.9	11.0	10.1	5.0	8.6	3.7	4.5	10.7	8.1	8.2	2.1	6.9
1971	Upper Matecumbe	119	55										
No. individual habitat samples		90	70										
Monthly average CPUE		1.32	.79										
% of total CPUE		62.6	37.4										

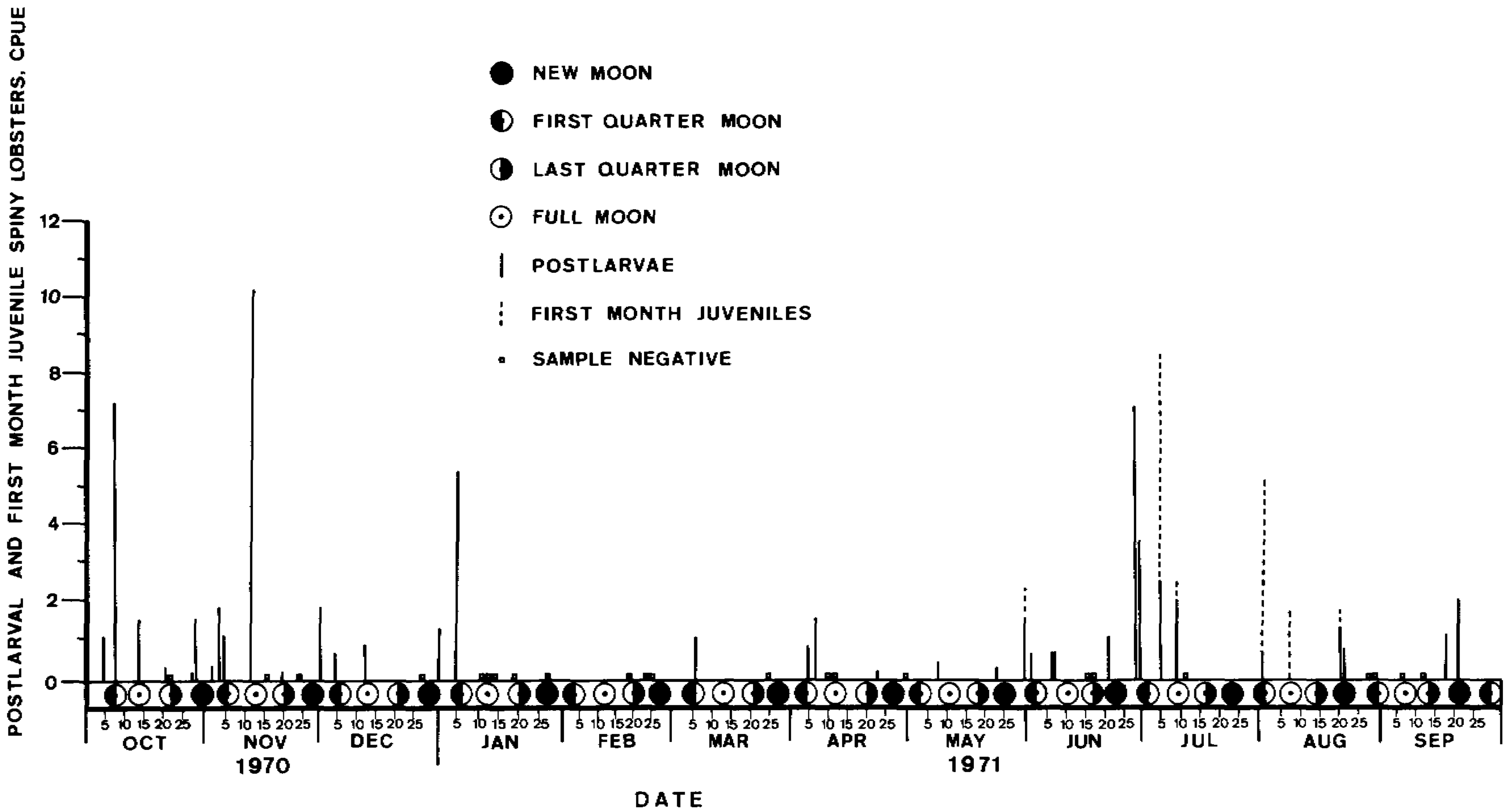

Figure 14. Postlarval and juvenile spiny lobster CPUE from Witham habitats at Boca Chica Key, Florida Keys, 1970 and 1971.

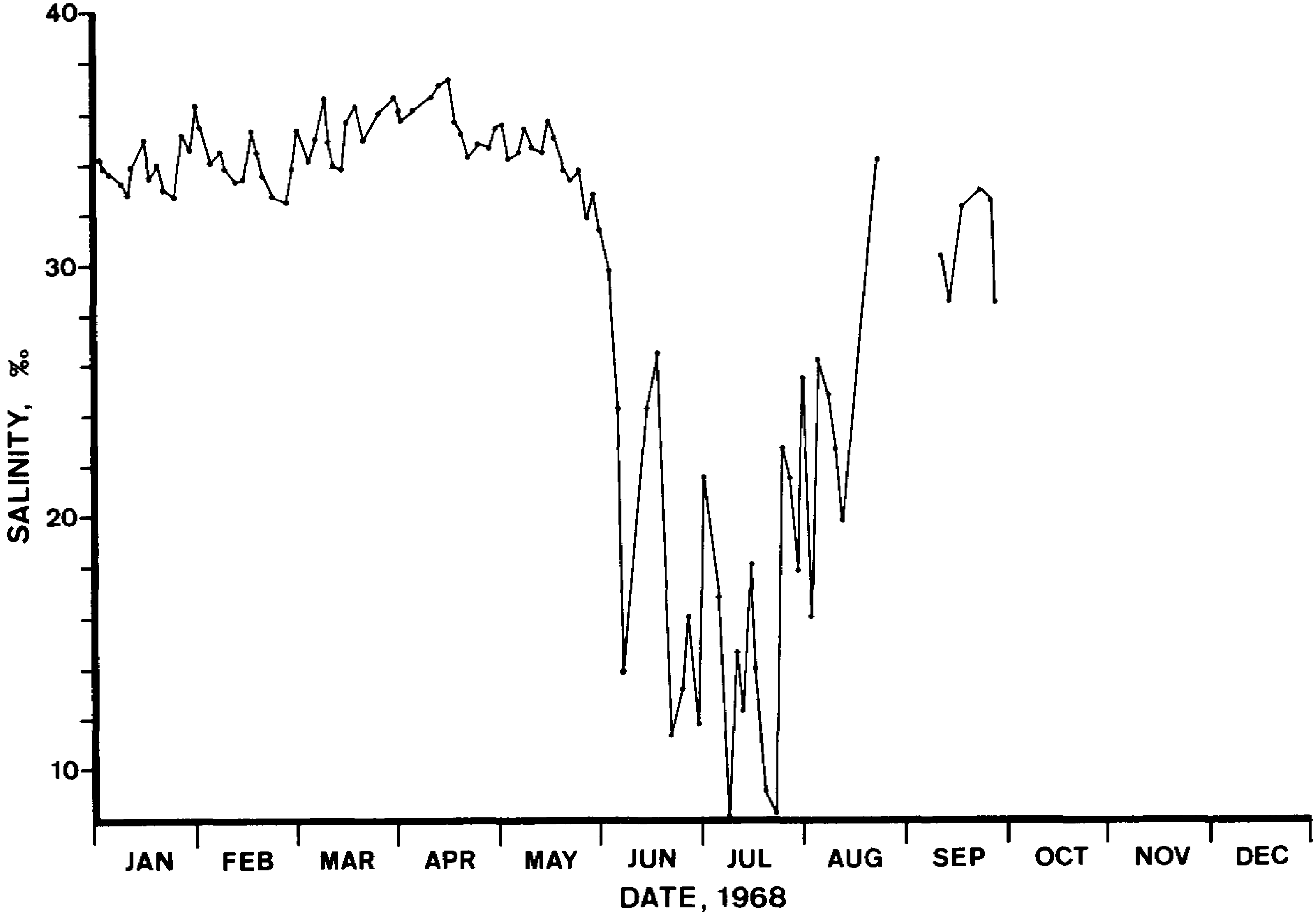

Figure 8. Salinities, House of Refuge dock, Indian River, 1968.

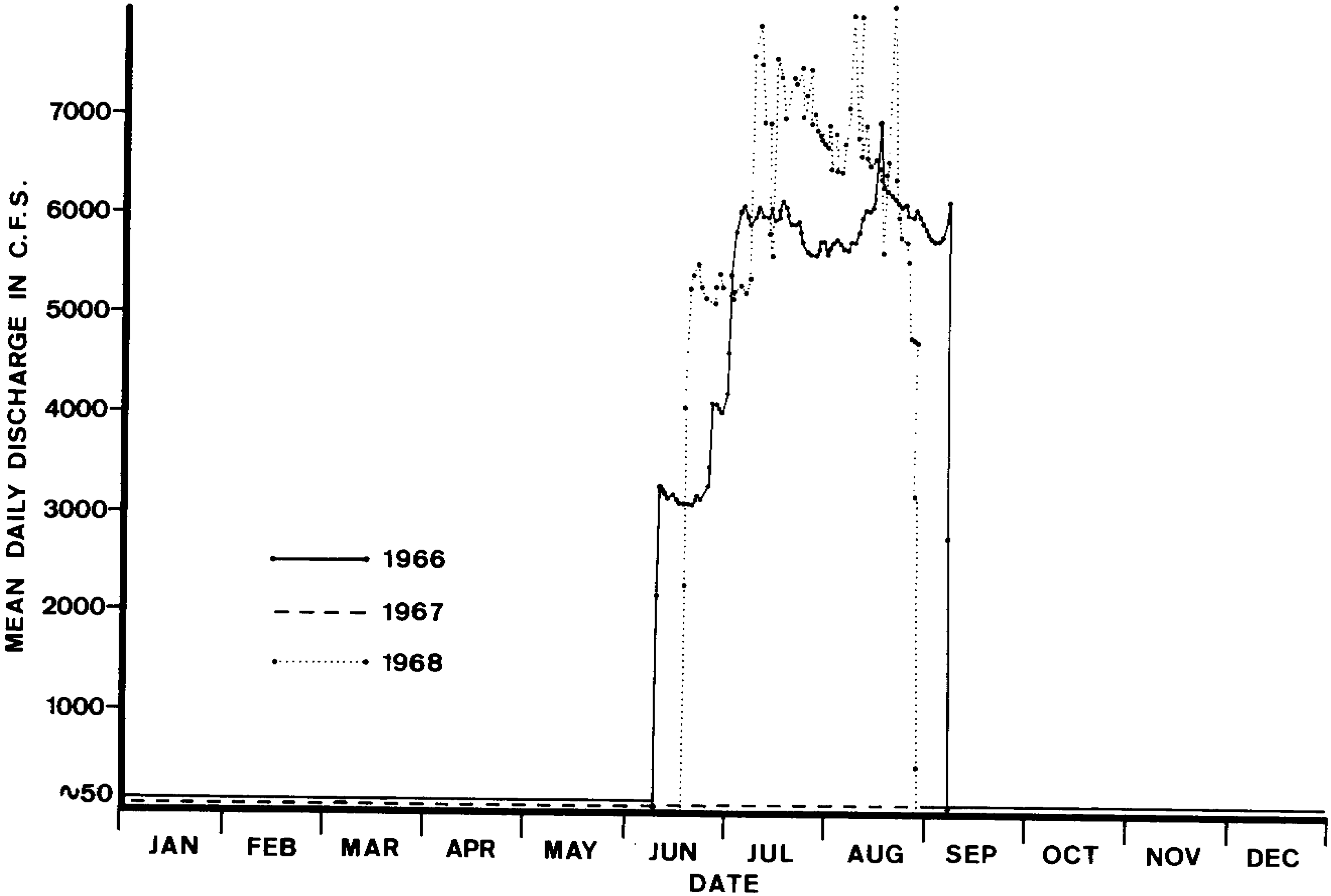

Figure 9. Freshwater discharges, cubic feet per second, (CFS), St. Lucie locks, 1966-1968.

TABLE 3. SURFACE WATER TEMPERATURES, DEGREES CELSIUS, HOUSE OF REFUGE DOCK (DEPTH 1.5 m). MOST MEASUREMENTS MADE BETWEEN 0800-1000 hr.

Month	Year	Number of Measurements	Range	$\bar{x}$	sd	$s\bar{x}$	$\bar{x}$ All Years
Jan	1966	31	10.0 - 23.0	18.2	2.84	.51	
	1967	30	15.8 - 23.2	20.4	1.98	.34	19.2
	1968	15	13.6 - 22.6	19.1	2.74	.74	
Feb	1966	28	11.0 - 24.0	17.4	8.71	1.56	
	1967	28	12.5 - 22.2	19.4	2.55	.48	18.1
	1968	11	13.6 - 21.4	16.6	2.56	.74	
Mar	1966	31	17.4 - 23.8	20.6	1.65	.30	
	1967	31	18.8 - 24.4	22.1	1.84	.33	20.8
	1968	11	13.6 - 21.8	18.3	2.62	.75	
Apr	1966	30	19.8 - 25.2	22.4	1.30	.24	
	1967	30	20.4 - 26.0	24.0	1.55	.28	23.3
	1968	12	21.0 - 26.0	24.0	1.47	.42	
May	1966	30	21.4 - 27.3	25.6	1.19	.21	
	1967	31	23.0 - 26.4	25.0	1.02	.18	25.3
	1968	14	23.4 - 28.0	25.3	1.16	.31	
Jun	1966	30	24.2 - 28.5	26.5	1.20	.21	
	1967	30	26.4 - 32.0	28.2	1.43	.26	27.2
	1968	11	24.2 - 29.2	26.2	1.56	.49	
Jul	1966	31	26.0 - 30.9	28.7	1.17	.22	
	1967	31	26.8 - 29.4	28.2	.85	.15	28.4
	1968	13	25.5 - 28.8	28.2	.49	.41	
Aug	1966	31	27.0 - 30.5	28.5	.79	.13	
	1967	31	26.6 - 31.4	28.6	1.07	.19	28.5
	1968	6	26.0 - 29.4	28.1	1.10	.30	
Sep	1966	30	27.4 - 30.2	28.5	.72	.13	28.2
	1967	24	26.0 - 30.0	28.0	.95	.20	
Oct	1966	31	23.0 - 28.5	26.2	1.52	.27	25.8
	1967	13	22.8 - 26.3	24.9	1.05	.29	
Nov	1966	31	14.8 - 24.2	20.4	4.47	.80	20.9
	1967	13	18.8 - 25.2	22.0	1.99	.53	
Dec	1966	31	14.0 - 23.0	18.3	3.02	.54	19.5
	1967	13	19.6 - 24.6	22.3	1.61	.43	

patterns noted at the House of Refuge dock and Reilly's dock in 1967 (Figure 10) further supports observations of lunar periodicity in recruitment.

FLORIDA KEYS

Whale Harbor mid-depth plankton sampling (Figure 11) provided first indications of patterns and mechanisms of postlarval recruitment to the Keys. Previous surface and bottom plankton studies at other Keys' bridges had been as generally unproductive (Robinson and Dimitriou, 1963b; Sims and Ingle, 1966), as subsequent efforts using these techniques (Table 10). Similar to the results at Indian River, much recruitment seems to have occurred in late winter and early spring. Transport of postlarvae to inshore areas by incoming night tides, which was first suggested by meager surface catches of planktonic postlarvae (Witham et al., 1968), was substantiated. Samples at Boca Chica Channel failed to take postlarvae on all ebb tides and on daylight flood tides. Postlarvae apparently are able to avoid being swept back to sea on ebb tides, as suggested for *Palinurus vulgaris* Latreille, 1804 (Orton and Ford, 1933).

Relationship of Airport Lagoon and Rest Beach 1967 Witham habitat data (Table 11) to actual magnitude of recruitment is unknown. Lunar periodicity (Figure 12) and similarity of many catches at the two sites seems more than

TABLE 4. CATCHES OF SPINY LOBSTER POSTLARVAE AND JUVENILES IN NATURAL HABITAT, INDIAN RIVER.

Date	Postlarvae Zone 1	Postlarvae Zone 2	Postlarvae Zone 3	Postlarvae Zone 4	Postlarvae Zone 5	Early Juveniles Zone 1	Early Juveniles Zone 2	Early Juveniles Zone 3	Early Juveniles Zone 4	Early Juveniles Zone 5
11 Aug 64		10					0			
18 Aug 64		12		5			0		0	
1 Sep 64	0	0				0	0			
14 Sep 64			4	0	0			0	0	0
13 Oct 64	0	20	2	0		0	2	4	0	
20 Oct 64					0					0
17 Nov 64	0	7	1			0	9	0		
24 Nov 64				0	0				0	0
18 Dec 64	0	3	4			0	0	1		
29 Dec 64				0	0				4	0
12 Jan 65	0	3	2			0	3	1		
21 Jan 65				0	0				0	0
18 Feb 65	0	3	1			10	13	2		
24 Feb 65				0	0				0	0
18 Mar 65	0	16	2			0	18	0		
29 Mar 65				4	0				0	0
14 Apr 65	0	42	0			0	18	4		
23 Apr 65				0	0				0	0
11 May 65	1	19	44	0	0	0	8	9	1	0
15 June 65	0	0	3			0	1	1		
22 June 65				0	0				0	0
7 July 65	0	2				0	8			
13 July 65			0	0	0			1	0	0
7 Aug 65	0	5	1			0	15	5		
13 Aug 65				0	2				1	0
Totals	1	142	64	9	2	10	95	28	6	0

TABLE 5. CATCHES OF SPINY LOBSTER POSTLARVAE AND JUVENILES IN NATURAL HABITAT, HOBE SOUND.

Date	Postlarvae Zone A	Postlarvae Zone B	Postlarvae Zone C	Postlarvae Zone D	Postlarvae Zone E	Early Juveniles Zone A	Early Juveniles Zone B	Early Juveniles Zone C	Early Juveniles Zone D	Early Juveniles Zone E
15 Sep 64	0	0	0	7	6	0	0	3	4	21
6 Oct 64	0	0	0	0	5	0	0	0	0	6
6 Nov 64	0	0	0	1	34	0	0	0	2	0
8 Dec 64	0	2	0	3	9	0	1	0	1	10
5 Jan 65	0	0	0	1	1	0	0	0	1	7
4 Feb 65	2	1	0	2	4	0	0	0	11	3
12 Mar 65	4	0	0	8	4	0	0	0	9	1
8 Apr 65	1	1	2	0	8	5	0	4	2	18
5 May 65	3	N.D.	N.D.	22	10	4	7	4	42	5
16 June 65	0	0	0	0	0	0	0	1	7	11
8 July 65	0	0	0	N.D.	N.D.	0	0	0	N.D.	N.D.
19 Aug 65	0	0	0	1	1	1	0	0	1	5
Totals	10	4	2	45	82	10	8	12	80	87

N.D. = no data.

TABLE 6. MONTHLY CATCH OF POSTLARVAL SPINY LOBSTERS, HOUSE OF REFUGE (H.R.) AND REILLY'S DOCK (R.D.), 1965 TO 1968.

					Month											
Year	Site	Habitat	Deployed	Removed	J	F	M	A	M	J	J	A	S	O	N	D
1965	H.R.	A	20 Apr 65					1	19	3	4	13	67	2	9	2
		B	16 Aug 65									3	81	1	12	0
		C	23 Sep 65										9	2	13	0
		D	10 Dec 65													3
Monthly totals								1	19	3	4	16	157	5	34	6
No. of individual habitat samples								3	5	4	5	7	31	90	90	114
Monthly average CPUE								.33	3.80	.75	.80	2.28	5.06	.05	.37	.05
% of total CPUE								2.4	28.2	5.6	5.9	16.9	37.5	0.4	2.7	0.4
1966	H.R.	A	20 Apr 65		2	0	0	5	19	0	0	0	0	0	7	1
		B	16 Aug 65		1	4	1	5	8	0	0	0	0	0	0	0
		C	23 Sep 65		0	4	0	2	0	0	0	0	0	0	1	0
		D	10 Dec 65	27 Sep 66	3	10	0	1	4	1	0	0	0	0		
		E	27 Sep 65											13	2	1
Monthly totals					6	18	1	13	31	1	0	0	0	13	10	2
No. individual habitat samples					120	112	124	120	124	120	124	124	120	124	120	124
Monthly average CPUE					.05	.16	.01	.11	.25	.01	0	0	0	.10	.08	.02
% of total CPUE					6.3	20.2	1.3	13.9	31.6	1.3	0	0	0	12.6	10.1	2.5
1967	H.R.	A	20 Apr 65	22 Nov 67	2	17	62	65	90	0	4	4	1	6	3	
		B	16 Aug 65			11	18	20	13	11	17	6	4	9	1	12
		C	23 Sep 65		1	23	29	18	5	13	8	3	7	6	10	42
		E	27 Sep 66	22 Dec 67	3	20	36	35	8	4	5	2	4	6	5	9
		F	23 Nov 67													107
Monthly totals					6	71	144	138	116	28	34	15	16	27	19	170
No. individual habitat samples					120	112	124	120	124	120	124	124	96	52	52	47
Monthly average CPUE					.05	.63	1.16	1.15	.94	.23	.27	.12	.16	.51	.36	3.61
% of total CPUE					0.5	6.8	12.6	12.5	10.2	2.5	2.9	1.3	1.7	5.5	3.9	39.3

TABLE 6. MONTHLY CATCH OF POSTLARVAL SPINY LOBSTERS, HOUSE OF REFUGE (H.R.) AND REILLY'S DOCK (R.D.), 1965 TO 1968 (Continued).

					Month											
Year	Site	Habitat	Deployed	Removed	J	F	M	A	M	J	J	A	S	O	N	D
1967	R.D.	X	23 Jan 67	19 Sep 67		16	11	8	5	0	1	2	1			
		Y	23 Jan 67	14 Aug 67		12	13	21	15	0	4	5				
Monthly totals						28	24	29	20	0	5	7	1			
No. individual habitat samples						56	62	60	62	60	60	59	7			
Monthly average CPUE						.50	.39	.48	.32	0	.08	.11	.14			
% of total CPUE						24.8	19.3	23.8	15.8	0	3.6	5.4	6.9			
1968	H.R.	B	16 Aug 65	4 Mar 68	2	0										
		C	23 Sep 65	27 Sep 68	1	4	9	27	3	0	0	0	0			
		F	12 Nov 67	4 Apr 68	41	11	34									
		G	4 Mar 68	7 May 68			2	60								
		H	8 Mar 68	1 Jun 68			3	62	28							
		I	4 Apr 68	27 Sep 68				30	28	2	0	0	0			
		J	4 Apr 68	27 Sep 68				163	57	0	0	0	0			
		K	7 May 68	27 Sep 68					7	2	0	0	0			
		L	1 Jun 68	27 Sep 68						0	0	0	1			
Monthly totals					44	15	48	342	123	4	0	0	1			
No. individual habitat samples					45	33	41	46	67	55	65	30	35			
Monthly average CPUE					.98	.45	1.17	7.43	1.83	.07	0	0	.03			
% of total CPUE					8.1	3.7	9.7	62.1	15.3	.6	0	0	.3			

TABLE 7. DISTRIBUTION OF CATCHES OF POSTLARVAL LOBSTERS, SUCCESSFUL CHECKS OF INDIVIDUAL WITHAM HABITAT, HOUSE OF REFUGE DOCK, 1967.

Date Examined	Individual Witham Habitat A	B	C	E	F
10 Jan	0	0	0	1	
12 Jan	0	0	0	1	
16 Jan	2	0	1	1	
Total	2	0	1	3	
1 Feb	1	0	0	0	
4 Feb	0	0	1	0	
7 Feb	0	0	3	0	
8 Feb	2	3	4	7	
9 Feb	0	0	2	3	
10 Feb	1	0	1	0	
12 Feb	1	0	0	1	
13 Feb	1	0	0	0	
14 Feb	1	1	1	0	
15 Feb	0	2	4	2	
16 Feb	2	0	3	1	
17 Feb	3	2	0	1	
18 Feb	3	1	2	1	
19 Feb	2	0	0	2	
20 Feb	0	2	1	0	
21 Feb	0	0	0	1	
22 Feb	0	0	0	1	
24 Feb	0	0	1	0	
Total	17	11	23	20	
1 Mar	0	0	0	1	
2 Mar	0	0	1	0	
4 Mar	0	0	1	0	
5 Mar	0	0	2	2	
6 Mar	8	3	3	3	
7 Mar	14	1	5	3	
8 Mar	4	0	1	2	
9 Mar	1	0	0	2	
10 Mar	0	0	1	4	
11 Mar	0	0	1	0	
12 Mar	9	0	0	2	
13 Mar	0	5	4	3	
14 Mar	3	1	3	3	
15 Mar	5	2	0	2	
16 Mar	14	2	4	4	
17 Mar	1	2	0	3	
18 Mar	2	0	0	0	
19 Mar	0	1	2	0	
20 Mar	0	0	0	1	
21 Mar	0	1	1	1	
25 Mar	1	0	0	0	
Total	62	18	29	36	
5 Apr	1	1	0	0	
7 Apr	10	1	1	7	
8 Apr	20	3	7	7	
9 Apr	4	1	1	1	
10 Apr	2	3	1	0	
11 Apr	2	2	3	4	
12 Apr	8	3	1	3	
13 Apr	6	3	2	3	
14 Apr	4	0	0	0	
15 Apr	4	0	0	3	
16 Apr	2	0	0	5	
17 Apr	1	1	0	2	

TABLE 7. DISTRIBUTION OF CATCHES OF POSTLARVAL LOBSTERS, SUCCESSFUL CHECKS OF INDIVIDUAL WITHAM HABITAT, HOUSE OF REFUGE DOCK, 1967. (Continued)

Date Examined	Individual Witham Habitat A	B	C	E	F
18 Apr	0	2	1	0	
20 Apr	0	0	1	0	
21 Apr	1	0	0	0	
Total	65	20	18	35	
4 May	8	1	0	0	
5 May	5	0	0	3	
6 May	3	1	0	0	
7 May	8	0	0	0	
8 May	12	1	2	1	
9 May	1	0	0	0	
10 May	2	0	0	0	
11 May	1	0	0	0	
12 May	11	3	0	0	
13 May	16	4	0	1	
14 May	9	1	3	1	
15 May	6	0	0	0	
16 May	7	2	0	2	
17 May	1	0	0	0	
Total	90	13	5	8	
6 Jun	0	1	0	0	
14 Jun	0	2	2	0	
15 Jun	0	2	3	0	
16 Jun	0	4	3	4	
17 Jun	0	2	4	0	
19 Jun	0	0	1	0	
Total	0	11	13	4	
1 Jul	0	1	0	0	
3 Jul	0	1	0	0	
4 Jul	1	0	0	0	
12 Jul	1	2	2	2	
13 Jul	0	0	0	1	
14 Jul	0	6	0	1	
18 Jul	0	1	1	0	
30 Jul	0	1	2	0	
31 Jul	2	5	3	1	
Total	4	17	8	5	
1 Aug	0	3	1	1	
2 Aug	2	2	2	0	
8 Aug	0	1	0	0	
29 Aug	0	0	0	1	
30 Aug	1	0	0	0	
31 Aug	1	0	0	0	
Total	4	6	3	2	
1 Sep	0	0	0	1	
3 Sep	1	0	0	0	
5 Sep	0	0	2	2	
6 Sep	0	0	1	0	
25 Sep	0	0	1	0	
27 Sep	0	0	1	0	
29 Sep	2	4	2	1	
Total	3	4	7	4	

TABLE 7. DISTRIBUTION OF CATCHES OF POSTLARVAL LOBSTERS, SUCCESSFUL CHECKS OF INDIVIDUAL WITHAM HABITAT, HOUSE OF REFUGE DOCK, 1967. (Continued)

Date Examined	Individual Witham Habitat A	B	C	E	F
2 Oct	1	3	1	2	
4 Oct	0	3	2	3	
6 Oct	3	2	3	1	
9 Oct	1	1	0	0	
16 Oct	1	0	0	0	
Total	6	9	6	6	
1 Nov	0	0	8	1	
3 Nov	1	1	0	4	
13 Nov	0	0	1	0	
27 Nov	1	0	1	0	
29 Nov	1	0	0	0	
Total	3	1	10	5	
1 Dec		0	11	3	12
4 Dec		2	14	3	18
6 Dec		3	4	1	17
8 Dec		4	2	1	8
11 Dec		2	7	0	12
13 Dec		1	2	0	17
15 Dec		0	2	1	4
18 Dec		0	0	0	4
29 Dec		0	0	0	15
Total		12	42	9	107

coincidental, yet there are exceptions. Disparities in simultaneous catches suggest postlarval influxes may be patchy; or, more likely, that other factors such as changes in attractiveness of habitat fouling assemblages, sampling bias, or ecological differences between sites may be important. Airport Lagoon and Rest Beach data demonstrate postlarval utilization of shoreward areas of Hawk Channel throughout the year. Unlike the postlarvae in the Indian River study, postlarvae here were common in midsummer. Such occurrence in the Keys was not unique. Limited habitat sampling at Marquesas Keys 40 km westward, from May through September 1967, produced most postlarvae and early juveniles during June and July.

Year-round postlarval availability, subject to lunar periodicity, was also indicated at Upper Matecumbe Key (Table 11, Figure 13) selected channels between Keys (Table 12), and Boca Chica Key (Figure 14). These catches, despite lack of confirmatory records from natural habitat, show that lobsters frequent Florida Keys waters less than one meter deep and less than 100 m from shore.

ENVIRONMENTAL FACTORS INFLUENCING RECRUITMENT

As shown by Sette (1943), Carruthers et al. (1951), Saville (1965), Jones et al. (1970), and others, thorough understanding of the biology of fishery species requires knowledge not only of times and places of recruitment, but also of physical and biological environmental factors affecting the process. Resolution of factors influencing patterns of postlarval lobster recruitment is difficult. Spawning rhythms and environmentally related changes in larval survival would be expected to contribute to seasonal and yearly recruitment variations. However, stocks of lobster larvae cannot readily be assessed because they are composed of long-lived, widely dispersed planktonic drifters which are difficult to quantitatively sample. Even seasonal and local geographic abundances of larvae cannot be determined with currently available techniques (Hammer, 1974).

Factors other than larval abundance could conceivably influence postlarval recruitment patterns. Lewis (1951), Sims and Ingle (1966), Hammer (1974), and Richards (1974) reported late stage palinurid larvae off Florida in all months. In most cases seasonal changes in abundance were not apparent. This may be a consequence of the various sources and current systems thought to contribute larvae to Florida. Accordingly, physiological and environmental factors causing differential success in metamorphosis and immigration to inshore areas might account for postlarval recruitment variations reported here.

TABLE 8. RECRUITMENT OF POSTLARVAL LOBSTERS TO SELECTED DISTANT WITHAM HABITATS.

Location	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total
	Number of Postlarvae Caught									
Sebastian Inlet	x	0	0	0	0	1	N.D.	0	0	1
Little Jim Island	0	0	0	0	0	0	0	0	0	0
Ft. Pierce Pier 66	x	0	0	0	0	18	3	1	0	22
Hobe Sound (County Line)	x	1	2	2	15	16	N.D.	0	0	36
Lake Worth at Singer Island	6	0	0	0	0	0	0	0	0	6
Totals	6	1	2	2	15	35	3	1	0	65

x—habitats not deployed.
N.D.—no data.

TABLE 9. PERCENTAGE OF MONTHLY POSTLARVAL RECRUITMENT BY MOON PHASE, BASED ON CPUE OF WITHAM HABITATS, 1967-1968.

	House of Refuge Dock, 1967				Reilly's Dock, 1967				House of Refuge Dock, 1968			
Month	NM	FQ	FM	LQ	NM	FQ	FM	LQ	NM	FQ	FM	LQ
Jan	33.3	66.0	0	0					66.7	28.8	4.4	0
Feb	40.8	53.5	2.8	2.8	40.0	50.0	0	10.0	87.5	12.4	0	0
Mar	41.2	26.3	.6	31.7	24.0	24.0	4.0	48.0	3.5	82.2	12.4	1.7
Apr	79.5	19.7	0	.8	100.0	0	0	0	85.9	12.8	.3	.8
May	53.6	29.4	0	14.2	55.5	22.2	11.0	11.0	46.2	51.6	1.4	.7
Jun	4.1	95.8	0	0	0	0	0	0	0	100.0	0	0
Jul	5.8	50.0	0	44.4	0	60.0	0	40.0	0	0	0	0
Aug	6.6	0	0	93.3	50.0	0	0	50.0	0	0	0	0
Sep	43.7	0	0	46.3	0	0	0	0	0	0	0	0
Oct	77.4	19.3	3.2	0								
Nov	78.9	0	5.2	15.7								
Dec	46.0	34.8	19.0	0								
$\bar{x}$	50.7	30.6	4.4	14.1	53.9	28.3	2.6	19.4	65.3	31.5	1.2	.7

The most practical approach to recruitment quantification is determination of changes in postlarval abundance. Information reported herein is not entirely adequate for this purpose, but is far more abundant than that concerning other aspects of the recruitment problem. It therefore seems worthwhile to briefly examine relationships between postlarval capture data and environmental factors.

Roessler and Rehrer (1971) noted that moon phase and light were principal determinants of short term changes in recruitment of postlarval pink shrimp, *Penaeus duorarum* Burkenroad, 1939, to south Florida nursery areas. The same appears to be true for lobsters. Recruitment occurs throughout the year and under differing hydrographic conditions, but invariably at night and predominantly between new and first quarter moons. Nocturnal planktonic occurrence of postlarvae agrees with tendency of larvae to rise to the surface at night (Sims and Ingle, 1966) and probably accounts for entrainment in surface and mid-depth plankton during night flood tides at Whale Harbor. Bright moonlight may retard vertical migration of postlarvae like it does for postlarval shrimp (Roessler and Rehrer, 1971). Such illumination has been shown to inhibit foraging of adult lobsters (Sutcliffe, 1956). Greater tidal exchange alone would not increase postlarval recruitment during new moon. Comparably strong tides also occur during full moon, but without proportionate recruitment increases.

The inverse relationship between light and postlarval lobster recruitment is not always consistent. During last quarter moon, flood tides occur in southeast Florida in the evening before moonrise (approximately midnight) (Roessler and Rehrer, 1971). Therefore, postlarvae would be carried shoreward in comparative darkness. However, recruitment is less then than during first quarter, when evening flood tides occur before moonset (approximately midnight). Cloud cover changes may influence recruitment to some degree, but constant differences between first and last quarter recruitment data indicate that factors other than light intensity may be involved. Although Hess (1940) and Lewis et al. (1952) report that *Panulirus argus* postlarvae avoid strong light, Schroeder (1965) noted a postlarval palinurid, possibly *P. argus*, swimming at the surface at night under a lantern. Phototactic responses are likewise inconsistent among other palinurids. Phillips (1972) reports that recruitment of the western Australian rock lobster, *P. longipes cygnus* George, 1962, occurs primarily during new moon, but Serfling and Ford (1975) found no lunar periodicity in postlarval recruitment of the California spiny lobster, *P. interruptus* Randall, 1839. Harada (1957) and Parker (1972) also report nocturnal attraction of postlarval *P. japonicus* Von Siebold, 1824 and *P. interruptus* to bright lights. The phenomenon is known for postlarvae of several scyllarids (Lyons, 1970). Perhaps such diverse responses result from differential reaction to natural ambient light as opposed to point sources of bright light at the surface.

Effects of light and lunar periodicity on postlarval recruitment need further study. Lunar periodicity may mask effects of other environmental factors, and make assessment of their influence difficult. Conversely, as in the case of postlarval shrimp (Roessler and Rehrer, 1971), other factors such as circulation anomalies may cause deviations from the lunar recruitment patterns.

Effects of temperature on postlarval spiny lobster recruitment cannot be assessed from existing data, but there are indications that temperatures normally occurring in southeast Florida do not directly control onset or magnitude of recruit-

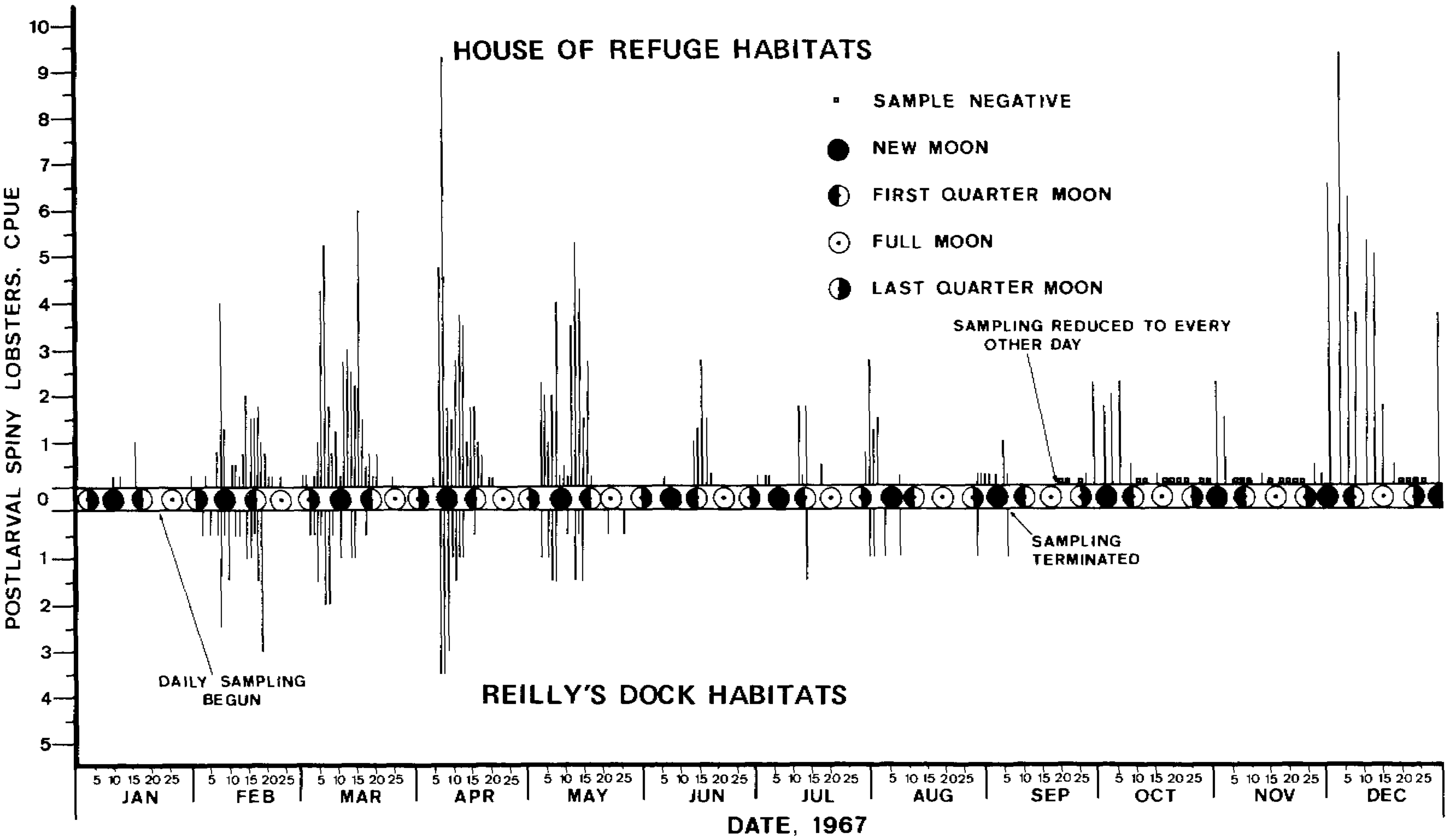

Figure 10. Postlarval spiny lobster CPUE from Witham habitats, House of Refuge and Reilly's dock, Indian River, 1967.

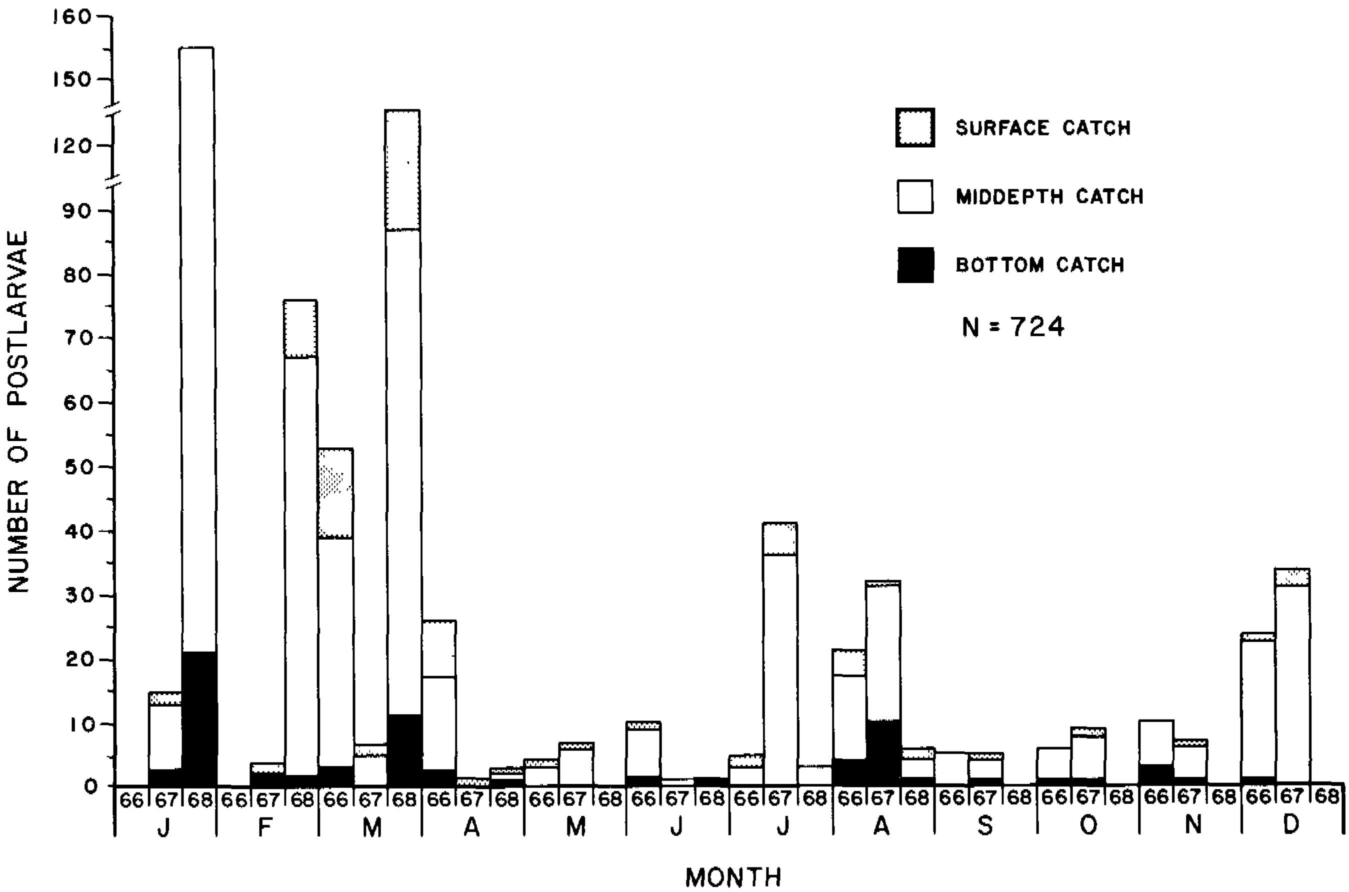

Figure 11. Monthly catches of postlarval spiny lobsters in plankton net sets, Whale Harbor, Florida Keys, March 1966 - August 1968.

ment. Postlarvae were collected from the Indian River and inshore waters of the Florida Keys during all months, but seasonal recruitment peaks fluctuated without apparent relationship to temperatures.

After postlarvae are recruited to shallow nursery grounds to begin their residence as juveniles, temperatures may influence growth, survival and ultimate fishery yield in much the same manner that Williams (1967) noted for juvenile shrimp. Witham (1973) found thermal tolerance in laboratory-maintained juvenile *P. argus* to be approximately 10.0-35.0°C; growth per molt decreased as these limits were approached. Temperatures recorded at the House of Refuge are within this range (Table 3), as are those reported for the Florida Keys (Vaughan, 1918; Chew, 1954; Jones, 1963; U. S. Dept. Comm., 1968; Hudson et al., 1970). Presence of juvenile lobsters throughout winter at the Indian River (Witham et al., 1968) and in Biscayne Bay throughout the year (Eldred et al., 1972) further indicates that temperature may not normally be a lethal limiting factor for south Florida lobster populations.

Salinities in deeper waters of the Florida Keys (Dole and Chambers, 1918; Chew, 1954; Jones, 1963) and off the southeast Florida coast (Parr, 1938; Wennekens, 1959; Vargo, 1968; Florida Ocean Science Institute, 1971) seldom vary beyond 35.0-39.0 ‰, and probably do not materially affect recruitment or survival of postlarval and juvenile lobsters. Greatly reduced salinities (≤20 ‰), however, disrupted recruitment at the House of Refuge in summers of 1966 and 1968. Similar effects might occur in other localities subject to substantial freshwater intrusion. Witham et al. (1968) found salinities of 19 ‰ lethal to laboratory-maintained postlarvae. Excessive rainfall runoff or release of impounded freshwaters (as occurs after hurricanes) to inshore nurseries might severely impact juvenile stocks, influencing subsequent yield of nearby lobster fisheries. Landings statistics necessary to investigate such relationships are presently unsuitable, lacking sufficient information on capture localities and catch effort.

TABLE 10. ABUNDANCE OF POSTLARVAL LOBSTERS IN NEW MOON, FLOODING TIDE SAMPLING WITH 0.5 m PLANKTON NETS, KEYS CHANNELS.

Month	Whale Hbr. Sur	Whale Hbr. Bot	Bow Chan. Sur	Bow Chan. Bot	Niles Chan. Sur	Niles Chan. Bot	Boca Chica Chan. Sur	Boca Chica Chan. Bot	Totals
Mar 66	12	0							12
Apr 66	12	0							12
May 66	1	0							1
Jun 66	1	0							1
Oct 66	0	0							0
Nov 66	0	0							0
Dec 66	1	3	0	1	1	2	1	0	9
Jan 67	0	*	0	0	0	0	0	1	1
Feb 67	1		2	0	2	0	0	0	5
Mar 67	42		1	0	0	0	0	0	43
Apr 67	0		0	1	0	0	2	1	4
May 67	1		0	0	0	0	0	0	1
Jun 67	0		0	0	0	0	0	0	0
Jul 67	4		1	0	2	0	0	0	7
Aug 67	5		0	0	0	0	0	0	5
Sep 67	0		3	0	1	0	0	0	4
Oct 67	*		0	0	0	0	0	0	0
Nov 67			0	2	0	0	1	0	3
Dec 67			0	0	0	0	0	0	0
Jan 68			1	2	1	1	2	0	7
Feb 68			0	0	0	0	0	0	0
Mar 68			5	0	0	3	0	0	8
Apr 68			0	0	0	0	1	0	1
May 68			0	0	0	0	0	0	0
Jun 68			0	0	0	0	1	0	1
Jul 68			1	0	0	0	0	0	1
Aug 68			2	1	0	0	0	0	3

* terminated

Recruitment reductions may occur if currents transporting postlarvae from the Florida Current to inshore nurseries are disrupted or weakened. If disruptions are extended, especially during peak recruitment periods, a situation analogous to year class failures of certain fishes might result. Conversely, if currents are especially favorable, atypically high recruitment may result.

The currents fluctuate which transport larvae through the Florida Straits and postlarvae to inshore nurseries. The Florida Current flows faster (Niiler and Richardson, 1973) and closer to shore (Hela, 1952b) during summer. Eddies (Florida Ocean Science Institute, 1971), meanders (Murray, 1952), and velocity changes (Niiler and Richardson, 1973) occur sporadically. This current consists of several distinct water masses of different origins, contributing to total transport in variable amounts (Wennekens, 1959). Relative contributions of larvae by each water mass is unknown. This current system and the tidal currents of southeastern Florida are also greatly influenced by coastal winds (Lee and Rooth, 1971). Although no wind data are available for the St. Lucie-Indian River area, those recorded at West Palm Beach Airport (26°41′30″N, 80°06′10″W) are probably representative of regional conditions. Patterns of wind velocity and direction were similar in 1967 and 1968 and resembled historical monthly means. Comparable patterns also occurred (Figure 15) at the Key West Airport (24°33′08″N, 81°45′36″W). Lower velocities at West Palm Beach may be due to inland location of that station. Absence of wide deviations from historical monthly means is significant. Aberrant wind conditions have been shown by Sette (1943), Carruthers et al. (1951), Chase (1955), and Saville (1965) to temporarily alter surface water circulation, which prevents sufficient larvae of certain fishes from reaching nursery grounds elsewhere. Apparently this was not a factor affecting postlarval lobster recruitment in years considered here. More accurate assessment of wind influence on circulation and postlarval lobster recruitment is difficult because existing hydrographic data is insufficient to indicate responses of the Florida Current and inshore tidal currents to wind effects.

Computation of tidal effects is complicated by the tendency for actual tidal conditions to differ substantially from those predicted (Borkowski, 1971). There is, however, a noticeable correlation among recruitment increases, higher wind velocities, and tidal amplitude increases in spring and autumn at House of Refuge. Normal recruitment patterns must be quantified and correlated with circulation regimes before relationships can be demonstrated or anomalies explained.

TABLE 11. MONTHLY ABUNDANCE OF LOBSTER POSTLARVAE, FLORIDA KEYS WITHAM HABITATS.

		Month											
Year	Site	J	F	M	A	M	J	J	A	S	O	N	D
1967	Airport Lagoon	8	16	4	145	26	22	53	30	5	5	0	23
No. individual habitat samples		7	8	8	8	10	8	6	10	2	4	6	5
Monthly average CPUE		1.14	2.00	.50	18.12	2.60	2.75	8.83	3.00	2.50	1.25	0	4.60
% of total CPUE		2.4	4.2	1.0	38.3	5.5	5.8	18.7	6.3	5.3	2.6	0	9.7
1967	Rest Beach	6	23	0	11	8	35	49	35	4	20	24	20
No. individual habitat samples		8	8	7	7	10	8	6	10	2	5	7	5
Monthly average CPUE		.75	2.88	0	1.57	.80	4.38	8.17	3.50	2.00	4.00	3.43	4.00
% of total CPUE		2.1	8.1		4.4	2.2	12.3	23.0	9.9	5.6	11.3	9.7	11.3
1969	Upper Matecumbe		12	25	44	21	13	39	94	47	28	11	5
No. individual habitat samples			9	13	23	14	6	26	60	51	36	18	9
Monthly average CPUE			1.33	1.92	1.91	1.50	2.17	1.50	1.57	.92	.78	.61	.56
% of total CPUE			9.0	13.0	13.0	10.2	14.7	10.2	10.6	6.2	5.3	4.1	3.8
1970	Upper Matecumbe	68	54	66	35	61	8	17	21	77	25	8	45
No. individual habitat samples		30	45	60	65	65	20	35	18	88	28	35	60
Monthly average CPUE		2.27	1.20	1.10	.54	.94	.40	.49	1.17	.88	.89	.23	.75
% of total CPUE		20.9	11.0	10.1	5.0	8.6	3.7	4.5	10.7	8.1	8.2	2.1	6.9
1971	Upper Matecumbe	119	55										
No. individual habitat samples		90	70										
Monthly average CPUE		1.32	.79										
% of total CPUE		62.6	37.4										

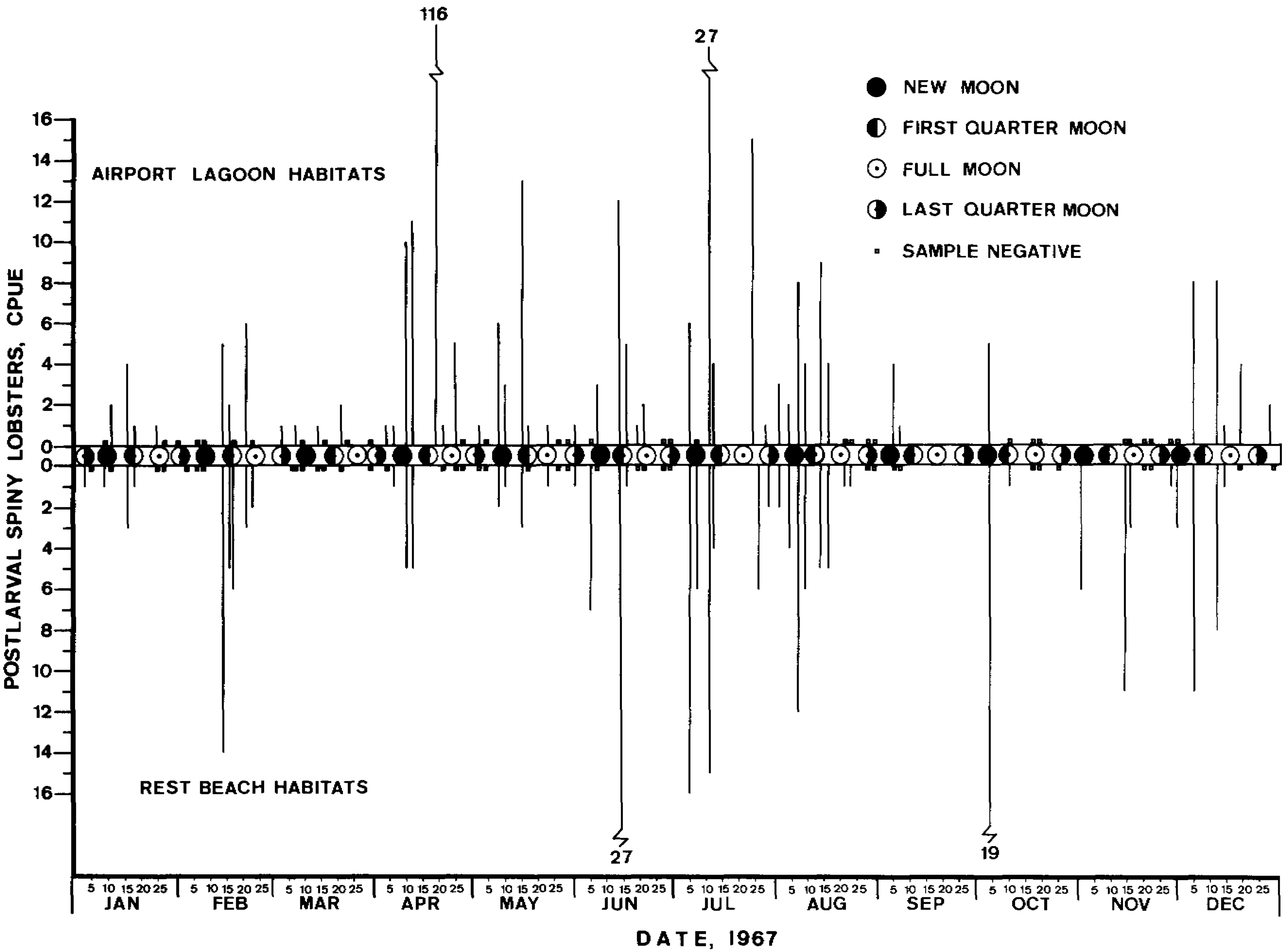

Figure 12. Postlarval spiny lobster CPUE from Witham habitats at Airport Lagoon and Rest Beach, Key West, 1967.

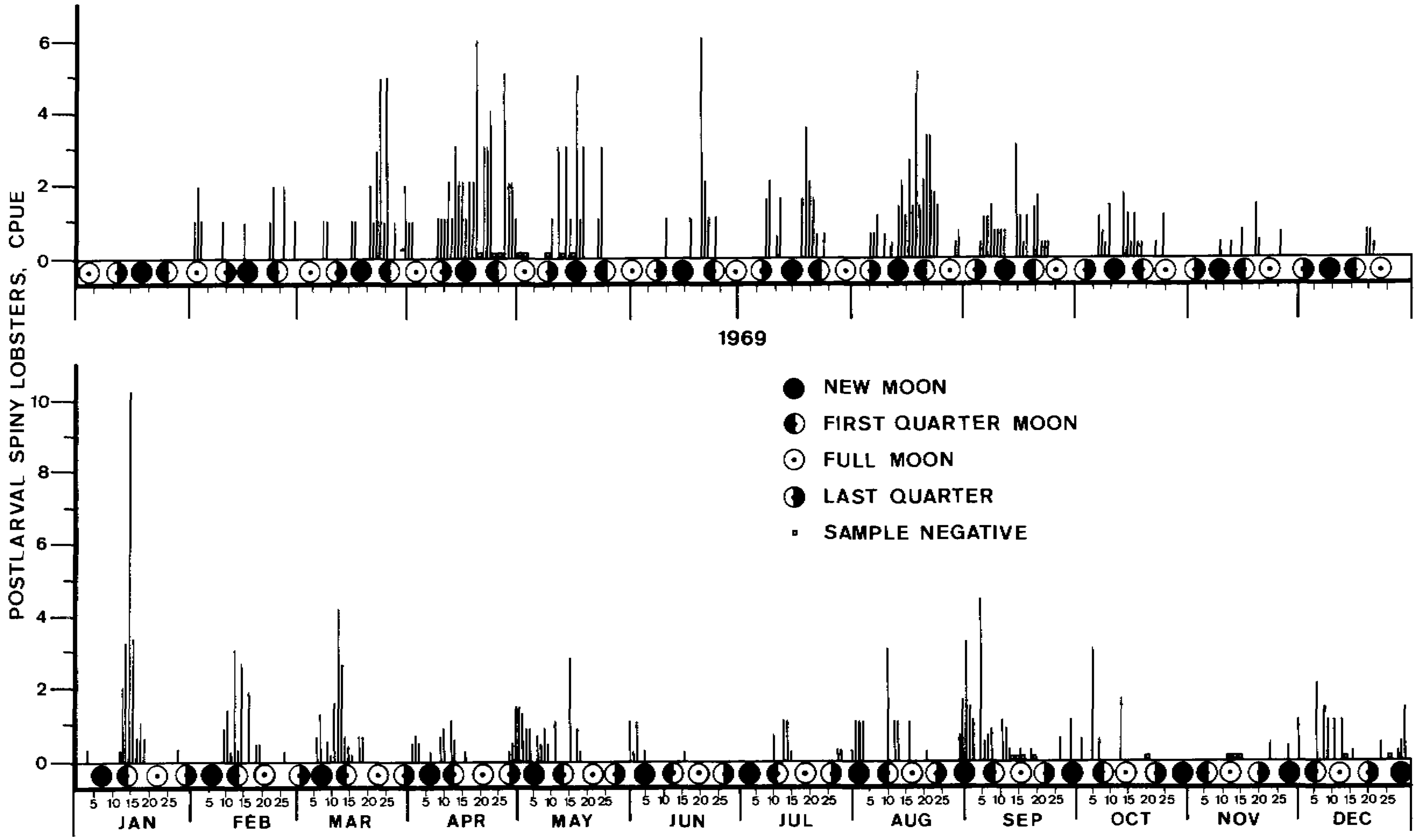

Figure 13. Postlarval and juvenile spiny lobster CPUE from Witham habitats at Upper Matecumbe Key, Florida Keys, 1969 and 1970.

TABLE 12. OCCURRENCE OF POSTLARVAE AND EARLY JUVENILES IN SUCCESSFUL CHECKS OF WITHAM HABITATS, KEYS CHANNELS, FEBRUARY THROUGH AUGUST, 1970.

Date	Moon Phase	STATIONS Postlarvae BC	SC	NC	PC	BH	CK	DK	WH	Juveniles BC	SC	NC	PC	BH	CK	DK	WH
2 Feb	LQ+3 days	0	0	0	0	0	0	0		0	0	0	0	0	1	0	0
9 Feb	FM+2	0	1	1	0	0	0	1		0	0	0	0	0	0	0	0
13 Feb	FQ−1	0	7	2	0		0	0		0	0	0	0	0	0	0	
16 Feb	FQ+2	0	0	1	0	0	0	0		0	0	0	0	0	0	0	
Total		0	8	4	0	0	0	1		0	0	0	0	0	1	0	0
3 Mar	LQ	0	0	0	0	0	0	0		0	1	0	0	0	0	0	
9 Mar	NM+1	0	1	0	0		0	0		0	0	0	0	0	0	0	
13 Mar	FQ−2	0	4		2		0	0		0	0	0	0		0	0	
16 Mar	FQ+1	1	0	1	0		0	0		0	0	0	0		0	0	
19 Mar	FQ+3					0			1					0			0
20 Mar	FM−3	0	1	0	0		0	2		0	0	0	0		0	0	
23 Mar	FM−1	0	0	0	0		1	0		0	0	0	0		0	0	
Total		1	6	1	2	0	1	2	1	0	1	0	0	0	0	0	0
3 Apr	LQ−3	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0
6 Apr	NM−1	0	0	0	0	0	0	0		1	0	0	0	0	0	0	
15 Apr	LQ+1								3								0
Total		0	0	0	0	0	0	0	4	2	1	0	0	0	1	0	0
4 May	NM−2	0	0	0	1	0	0	0		0	0	0	0	1	0	0	
6 May	NM								1								0
8 May	NM+2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
11 May	FQ−3	0	0	0	0	0	0	2		0	0	0	0	0	0	0	
15 May	FQ+1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	
22 May	FM	0	0	0	0	0	0	0		0	0	0	1	0	0	0	
Total		0	0	0	1	0	1	3	1	0	0	0	1	1	0	0	0
2 Jun	NM−3	0	0	0	0	1	0	1		0	0	0	0	0	1	0	
5 Jun	NM	0	1	0	0	2	0	0	2	0	0	0	0	0	0	0	0
9 Jun	NM+3	0	0		0	0	0	0		0	0	0	0	1	0	0	
Total		0	1	0	0	3	0	1	2	0	0	0	0	1	1	0	0
10 Jul	FQ−3	0	0	1	0	1	0	0		0	0	0	0	0	0	0	
17 Jul	FM−2								0								1
Total		0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
6 Aug	NM+3	0	0	0	0	0	2	0		0	0	0	0	0	3	0	
7 Aug	FQ−3	0	0		1	0	0	0	1	3	2		0	0	1	0	0
11 Aug	FQ	0	0	0	2	0	1	0		0	0	0	0	0	0	0	
14 Aug	FQ+3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
18 Aug	FM	0	0	0	0	0	0	0		0	0	0	0	0	3	0	
20 Aug	FM+1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Total		0	0	0	3	0	3	0	1	4	3	0	0	0	7	0	0
TOTALS		1	15	6	6	4	5	7	9	6	5	0	1	2	10	0	1

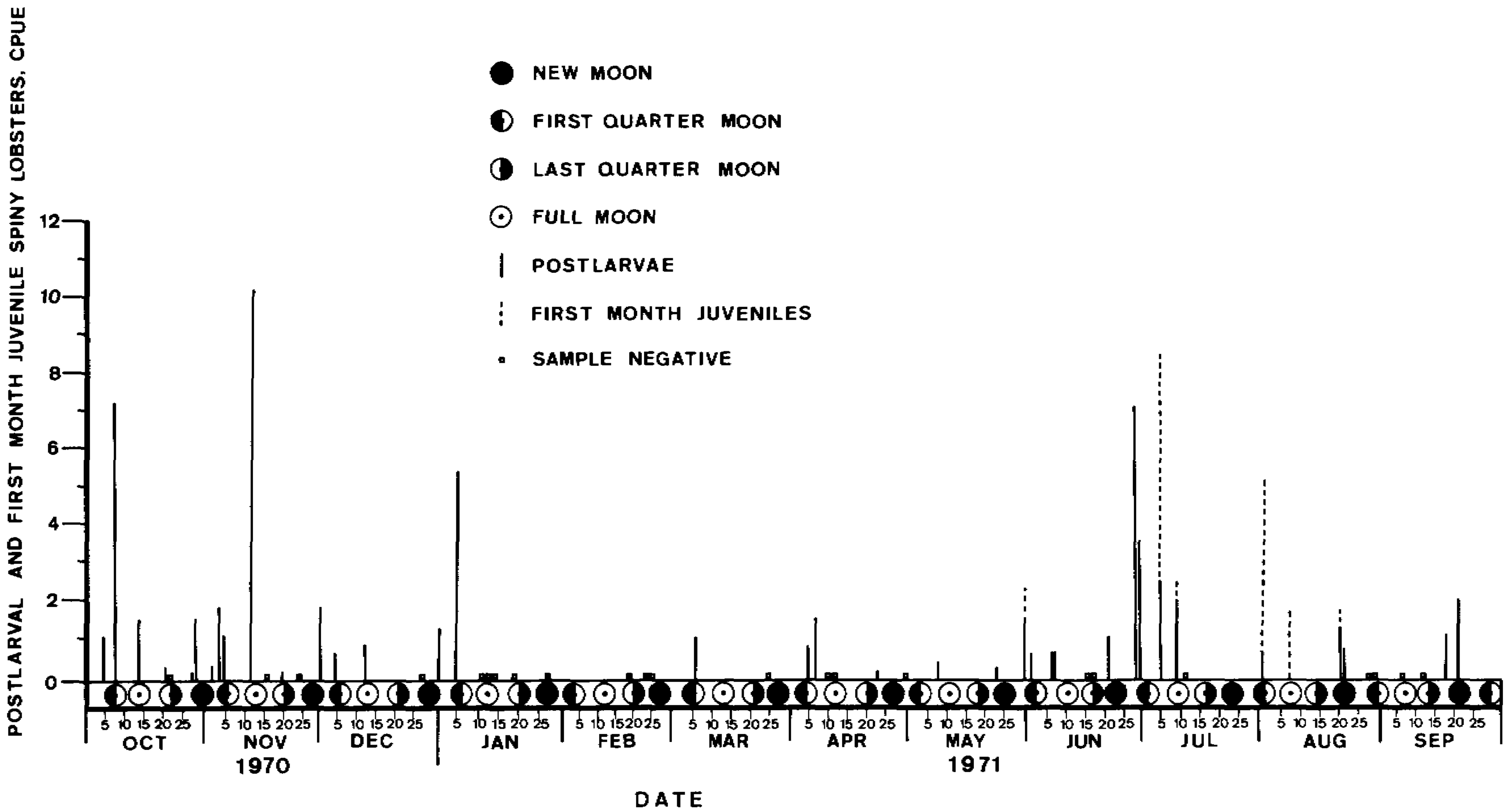

Figure 14. Postlarval and juvenile spiny lobster CPUE from Witham habitats at Boca Chica Key, Florida Keys, 1970 and 1971.

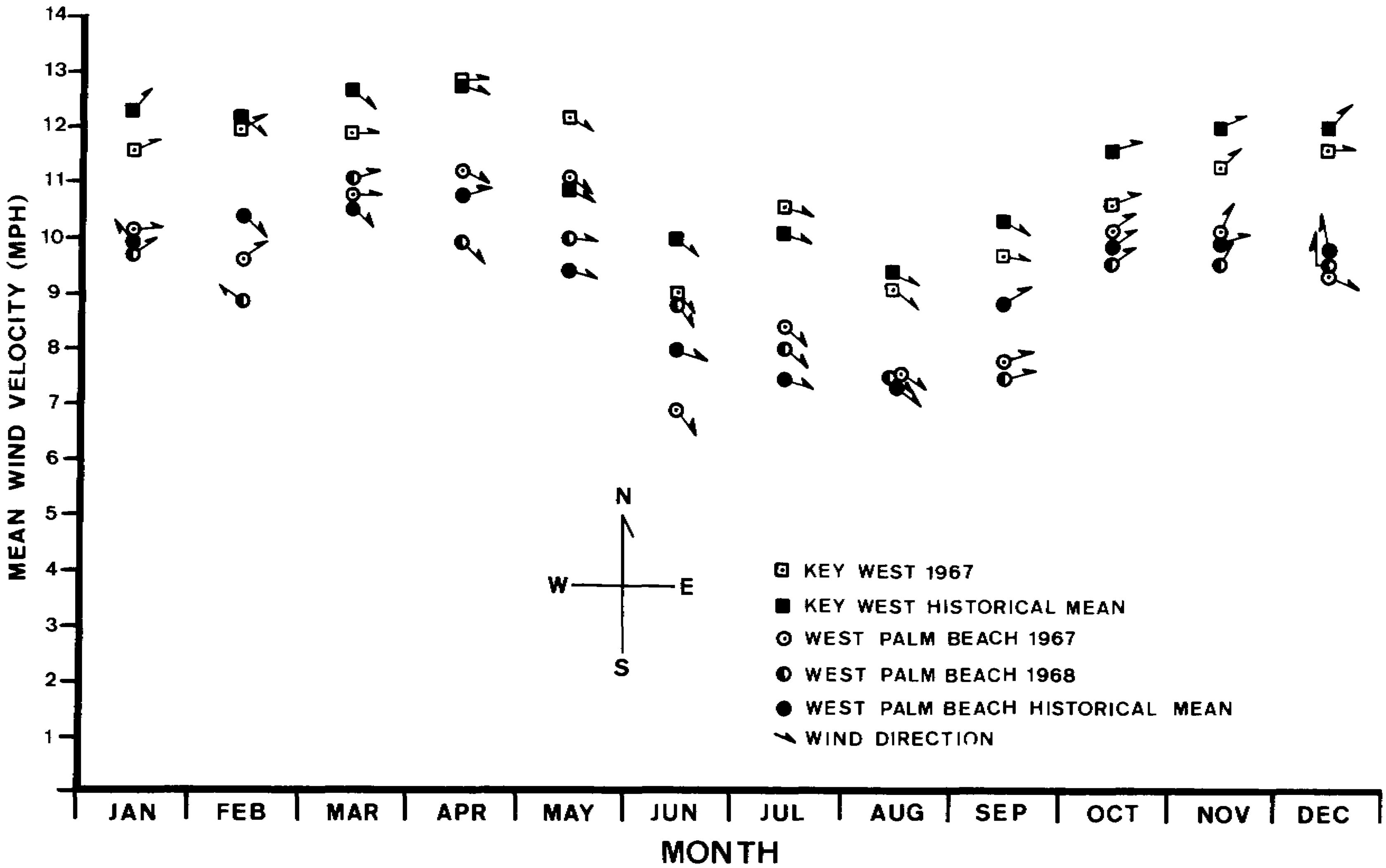

Figure 15. Mean monthly wind velocities and directions, Key West and West Palm Beach.

Light, temperature, salinity, and circulation are not the only environmental factors that may influence patterns of postlarval recruitment. In accord with the characteristic complexity of marine ecosystems, several less obvious factors may also be of consequence. Those seemingly warranting further investigation include fluctuations in predation on postlarvae, availability of natural habitat, and turbidity.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Present understanding of dynamics, mechanisms, and implications of postlarval recruitment is inadequate. Data are neither truly quantitative nor of proven accuracy. Uncertainty of the role of deeper water offshore nurseries limits the confidence to be placed on hypotheses based solely upon inshore recruitment studies. Still, some valuable insights into biology of the Florida lobster resource have been gained. Perhaps most significant is demonstration of the utilization of inshore areas. Alteration or degradation of such areas constitutes a threat to continued lobster productivity. Similar habitat utilization by juvenile *P. argus* in Cuba (Buesa Más, 1969), the Virgin Islands (Olsen et al., 1971), the Lesser Antilles (Peacock, 1974), and Brazil (Costa et al., 1969) substantiate this concern.

Southeastern Florida is the continental northern limit for commercially abundant *P. argus*. Chittleborough (1970), working on juvenile *P. longipes cygnus*, suggested that at such limits, density independent factors (especially temperature) play a greater role in juvenile production than do density dependent factors (especially competition). Populations in warm temperate southeast Florida estuaries are probably more susceptible to environmental change than Florida Keys tropical populations. Density dependent factors, such as available habitat, would thus be expected to assume greater importance in the Keys.

Postlarvae have been found in all months, but peak influxes have usually occurred between February and June and between September and December. This pattern may be less pronounced in the lower Florida Keys, where high summer influxes have also been noted. The contention of Lewis et al. (1952) that peak recruitment occurs in January is not necessarily contradictory; substantial numbers of postlarvae have been taken during that time in some data reported here. Year-round recruitment of postlarvae, with two abundance peaks, is reported for *P. argus* in Cuba (Buesa Más, in litt.), the Lesser Antilles (Peacock, 1974), and northeastern Brazil (Costa et al., 1969). Johnson (1971) and Peacock (1974) postulate that palinurid recruitment peaks result from intermittent arrival of favorable oceanic eddies, and that such are ultimately responsible for changes in annual stocks.

Limited applicability of existing data is a consequence of the preliminary nature of this investigation. However, frequent and widespread recruitment to Witham type habitats in inshore waters suggests that this device can be a useful tool for assessing certain aspects of lobster population dynamics. After several localities conducive to recruitment are identified, more quantitative habitat sampling programs, in conjunction with other investigative techniques, can be undertaken to establish relationships among recruitment, juvenile survival, and adult stocks.

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